# Longevity Risk and Capital Markets: The 2024-25 Update

David Blake[+]

27 September 2026

**Abstract**

We discuss the papers presented at *Longevity 19: The Nineteenth International Longevity Risk and Capital Markets Solutions Conference* that was held in Amsterdam on 16-17 September 2024. We also discuss (1) the development of the longevity risk transfer market since it started in 2005-06 and (2) key factors that will affect the future of the market: peak cash flows; the volatility of life expectancy trends; population aging; the aging process and anti-aging treatments; preventative health care and later life wellness; artificial intelligence, machine learning, robotics, and quantum computing; the implications of global aging for financial markets and economic growth; and climate change and sustainable development.

**Key words**: longevity risk transfer, capital markets
**JEL**: G15, G22, G23, J11, O31, Q01, Q54

**Supplementary Material**
Virtual Special Issue of *Insurance: Mathematics and Economics* on
Longevity Risk and Capital Markets Solutions, 2026
https://www.sciencedirect.com/special-issue/10322519XKV

Supplementary Material available here:
https://ars.els-cdn.com/content/image/1-s2.0-S0167668726000995-mmc1.pdf

[+] David Blake [D.Blake@city.ac.uk] is Professor of Finance and Director of the Pensions Institute, Bayes Business School, City St George's, University of London, UK. David Blake and Richard MacMinn are co-founders of the *Longevity Risk and Capital Markets Solutions Conferences*. We are extremely grateful to Marilyn Parris-Bell and Mike Mansfield for their superb organization of the conference. This article updates previous annual reviews in the Longevity Risk and Capital Markets series; the 2023-24 update is available here: https://static-content.springer.com/esm/art%3A10.1007%2Fs13385-025-00421-y/MediaObjects/13385_2025_421_MOESM1_ESM.pdf

**Table of contents**


**2005: Longevity 1** ..... 1
**2006: Longevity 2** ..... 2
**2007: Longevity 3** ..... 2
**2008: Longevity 4** ..... 3
**2009: Longevity 5** ..... 4
**2010: Longevity 6** ..... 4
**2011: Longevity 7** ..... 5
**2012: Longevity 8** ..... 6
**2013: Longevity 9** ..... 7
**2014: Longevity 10** ..... 8
**2015: Longevity 11** ..... 10
**2016: Longevity 12** ..... 12
**2017: Longevity 13** ..... 13
**2018: Longevity 14** ..... 21
**2019: Longevity 15** ..... 25
**The introduction of third-party capital** ..... 31
**2020** ..... 34
***Longevity risk transfers*** ..... 34
***The Covid-19 pandemic*** ..... 46
**2021: Longevity 16** ..... 49
**2022: Longevity 17** ..... 54
**2023: Longevity 18** ..... 72
**2024** ..... 91
**2025** ..... 113
**Securitizing mortality risk** ..... 136
**Setbacks** ..... 137
**Academic contributions** ..... 138
**Looking into the future** ..... 143
***Peak cash flows*** ..... 143
***The volatility of life expectancy trends*** ..... 144
***Population aging*** ..... 151

*The aging process and anti-aging treatments* ..... 162
*Preventative health care and later life wellness* ..... 180
*Artificial intelligence, machine learning, robotics and quantum computing* ..... 195
*Implications of global aging for financial markets and economic growth* ..... 205
*Climate change and sustainable development* ..... 212
**The problem: climate change** ..... 212
**The solution: sustainable development** ..... 222
The UK's response ..... 223
The European Union's response ..... 224
COP26 – November 2021 ..... 229
Transition planning ..... 232
Pension scheme responses ..... 234
The UK ..... 234
The European Union ..... 241
The US ..... 245
Global ..... 246
Large pension schemes ..... 247
Smaller pension schemes ..... 253
Recent developments ..... 254
UN-supported initiatives relating to asset owners, asset managers, insurers and banks 256
Principles for Responsible Investment ..... 256
Net-Zero Asset Owner Alliance ..... 259
Net Zero Asset Managers initiative ..... 262
Net-Zero Insurance Alliance ..... 268
Net-Zero Banking Alliance ..... 268
Multi-national and multi-industry initiatives ..... 270
Carbon Disclosure Project and the Science Based Targets initiative ..... 270
Institutional Investors Group on Climate Change ..... 271
Global Impact Investing Network and Catalytic Capital Consortium ..... 273
Network for Greening the Financial System and Climate Financial Risk Forum ..... 274
Climate Finance Leadership Initiative ..... 275
Mirova and Robeco fund manager-led initiative to standardize the calculation of avoided emissions ..... 275

Allianz's dashboard to track the transition pathway to net zero ..... 276
International Organization of Securities Commissions' initiative for companies world-wide to adopt sustainability-related financial disclosure standards ..... 276
Accounting for Sustainability ..... 277
Net Zero Engagement Initiative ..... 277
Just transition networks ..... 278
International collaboration between pension funds ..... 279
Industrial Transition Accelerator ..... 279
The OECD's Climate Adaptation Investment Framework ..... 280
University-based research programs on climate change and solutions ..... 280
Industry-based research programs on climate change and solutions ..... 281
COP28 – December 2023 ..... 283
2024 developments in sustainability ..... 288
COP29 – November 2024 ..... 295
2025 developments in sustainability ..... 297
COP30 – November 2025 ..... 323
Three key sustainability issues: biodiversity, natural capital and the circular economy ..... 324
Biodiversity ..... 325
Natural capital ..... 327
Circular economy ..... 336
Investment and sustainability ..... 337
Integrating biodiversity into finance ..... 337
The financial sector's pathway to sustainable investing ..... 338
The drivers of investment funds' allocation to sustainable investments ..... 340
Building sustainable investment strategies ..... 341
Climate betas ..... 347
Why global temperatures matter for asset pricing ..... 349
Constructing climate-risk hedge portfolios ..... 349
The performance of ESG portfolios ..... 351
Exploiting climate-related share mispricing ..... 353
The Sustainability Dividend and the value of climate patents ..... 354
Sustainable investing and the growth in artificial intelligence ..... 355
Implications ..... 356

**Longevity 19** ..... 357
**References** ..... 390

This Special Issue of *Insurance: Mathematics & Economics* contains 17 contributions to the academic literature all dealing with longevity risk and capital markets.[1] Draft versions of the papers were presented at *Longevity 19: The Nineteenth International Longevity Risk and Capital Markets Solutions Conference* that was held in Amsterdam on 16-17 September 2024. The conference was hosted by the Research Centre for Longevity Risk at the University of Amsterdam and the Pensions Institute at Bayes Business School, City St George's, University of London.

Longevity risk and related capital market solutions have grown increasingly important in recent years, both in academic research and in the markets we refer to as the Life Market, i.e., the capital market that trades longevity- and mortality-linked assets and liabilities.[2] Mortality improvements around the world are putting more and more pressure on governments, pension funds, life insurance companies, as well as individuals, to deal with the longevity risk they face. At the same time, capital markets can, in principle, provide vehicles to hedge longevity risk effectively and transfer the risk from those unwilling or unable to manage it to those willing to invest in this risk in exchange for appropriate risk-adjusted returns or to those who have a counterbalancing risk that longevity risk can hedge, e.g., life offices and reinsurers with mortality risk on their books. Many new investment products have been created both by the insurance/reinsurance industry and by the capital markets. Mortality catastrophe bonds are an early example of a successful insurance-linked security. Some new innovative capital market solutions for transferring longevity risk include longevity (or survivor) bonds, longevity (or survivor) swaps, mortality (or *q*-) forward contracts and reinsurance sidecars (also called strategic reinsurance vehicles). The aim of the *International Longevity Risk and Capital Markets Solutions Conferences* is to bring together academics and practitioners from all over the world to discuss and analyze these exciting new developments.

**2005: Longevity 1**

The conferences have closely followed the developments in the market. The first conference (*L1*) was held at Bayes Business School[3] in London in February 2005. This conference was prompted by the announcement of the Swiss Re Vita mortality catastrophe bond in December 2003 and the European Investment Bank/BNP Paribas/PartnerRe longevity bond in November 2004.

[1] The Guest Editors of the Special Issue were Professor David Blake, Professor Andrew J. G. Cairns (Director of the Duncan Laboratory for Insurance Data Science at Heriot-Watt University, UK) and Professor Dr Torsten Kleinow (Director of the Research Centre for Longevity Risk at the University of Amsterdam in The Netherlands).
[2] Blake et al. (2013).
[3] Formerly Cass Business School.

## 2006: Longevity 2

The second conference (*L2*) was held in April 2006 in Chicago and hosted by the Katie School at Illinois State University.[4] Since *L1*, there have been further issues of mortality catastrophe bonds, as well as the release of the Credit Suisse Longevity Index. In the UK, new life companies backed by global investment banks and private equity firms were setting up for the express purpose of buying out the defined benefit (DB) pension liabilities of UK corporations.[5] Goldman Sachs announced it was setting up such a buy-out company itself (Rothesay Life) because the issue of pension liabilities was beginning to impede its mergers and acquisitions activities. It decided that the best way of dealing with pension liabilities was to remove them altogether from the balance sheets of takeover targets. So there was firm evidence that a new global market in longevity risk transference had been established. However, as with many other economic activities, not all progress follows a smooth path. The EIB/BNP/PartnerRe longevity bond did not attract sufficient investor interest and was withdrawn in late 2005. A great deal, however, was learned from this failed issue about the conditions and requirements needed to launch a successful capital market instrument.

## 2007: Longevity 3

The third conference (*L3*) was held in Taipei, Taiwan on 20-21 July 2007. It was hosted by National Chengchi University.[6] It was decided to hold *L3* in the Far East, not only to reflect the growing importance of Asia in the global economy, but also to recognize the fact that population aging and longevity risk are problems that affect all parts of the world and that what we need is a global approach to solving these problems.[7] Since the Chicago conference, there had been a number of new developments, including: the release of the LifeMetrics Indices covering England & Wales, the US, Holland and Germany in March 2007 by J.P. Morgan, the Pensions Institute and Towers Watson;[8] the world's first publicly announced longevity swap between Swiss Re and the UK life office Friends Provident in April 2007 (although this was structured as an insurance or indemnification contract rather than a capital market transaction).

---

[4] The conference proceedings for *L2* were published in the December 2006 issue of the *Journal of Risk and Insurance*.

[5] With a buy-out, an insurance company buys out the liabilities of a pension scheme which is paid for with the pension scheme assets and a loan if the scheme is in deficit at the time. Both the pension scheme assets and liabilities are removed from the corporate sponsor's balance sheet. Each member has a personal annuity from the insurer who takes over responsibility for paying the pensions. This contrasts with a buy-in, where the liabilities remain on the sponsor's balance sheet, but the scheme buys a bulk purchase annuity (BPA) from an insurance company and pays members' pensions from the annuity payments it receives from the insurer. The BPA is an asset of the scheme, not the members. A BPA is more commonly known as a group annuity in other countries, such as the US and Canada.

[6] The conference proceedings for *L3* were published in the Fall 2008 issue of the *Asia-Pacific Journal of Risk and Insurance*.

[7] In fact, Asia has the world's largest and fastest growing aging population (United Nations, 2007).

[8] www.lifemetrics.com

Since the Taiwan conference, there were further developments in the capital markets. In December 2007, Goldman Sachs launched a monthly index suitable for trading life settlements.[9] The index, QxX.LS, was based on a pool of 46,290 anonymized US lives over the age of 65 from a database of life policy sellers assessed by the medical underwriter AVS. In 2008, Institutional Life Services (ILS) and Institutional Life Administration (ILA), a life settlements trading platform and clearing house, were launched by Goldman Sachs, Genworth Financial, and National Financial Partners. ILS and ILA were designed to modernize dealing in life settlements and meet the needs of consumers by ensuring permanent anonymity of the insured and of the capital markets by providing a central clearing house for onward distribution of life settlement assets, whether individually or in structured form.[10]

**2008: Longevity 4**

The fourth conference (*L4*) was held in Amsterdam on 25-26 September 2008. It was hosted by the Netspar Network for Studies on Pensions, Aging and Retirement and the Pensions Institute.[11]

Xpect Age and Cohort Indices were launched in March 2008 by Deutsche Börse. These indices cover, respectively, life expectancy at different ages and survival rates for given cohorts of lives in Germany and its regions, Holland and England & Wales.

The world's first capital market derivative transaction, a $q$-forward contract[12] between J. P. Morgan and the UK pension fund buy-out company Lucida, took place in January 2008. The world's first capital market longevity swap was executed in July 2008. Canada Life hedged £500m of its UK-based annuity book (purchased from the defunct UK life insurer Equitable Life). This was a 40-year swap customized to the insurer's longevity exposure to 125,000 annuitants. The longevity risk was fully transferred to investors, which included hedge funds and insurance-linked securities (ILS) funds. J. P. Morgan acted as the intermediary and assumed counter-party credit risk. In August 2011, ITV, the UK's largest commercial TV producer, completed a £1.7bn bespoke longevity swap with Credit Suisse for its £2.2bn pension plan: the cost of the swap is reported as £50m (3% of the swap value). The largest to date in the UK, covering £16bn of pension liabilities, was the longevity swap for the British Telecom Pension Scheme, arranged by the Prudential Insurance Co of America (PICA)[13] in July 2014. In February 2010, Mercer launched a pension buy-out index for the UK to track the cost charged by insurance companies to buy out corporate pension liabilities: at the time of launch, the cost was some 44% higher than

[9] Life settlements are traded life policies. In April 2007, the Institutional Life Markets Association started in New York, as the dedicated institutional trade body for the life settlements industry.
[10] In 2010, National Financial Partners became the sole owner of ILS/ILA.
[11] The conference proceedings for *L4* were published in the February 2010 issue of *Insurance: Mathematics and Economics*.
[12] Coughlan et al. (2007).
[13] We will use PICA to refer to the US-based insurer, which is a Prudential Financial Inc. company, as well as Prudential Retirement and Prudential Retirement Insurance and Annuity Company (PRIAC).

the accounting value of the liabilities which highlighted the attraction of using cheaper alternatives, such as longevity swaps.[14]

Also in 2008, Credit Suisse initiated a longevity swap with Centurion Fund Managers, whereby Centurion acquired a portfolio of synthetic (i.e., simulated) life policies, based on a longevity index built by Credit Suisse.

**2009: Longevity 5**

The fifth conference (*L5*) was held in New York on 25-26 September 2009.[15]

In 2009, survivor swaps began to be offered to the market based on Deutsche Börse's Xpect Cohort Indices.

**2010: Longevity 6**

The sixth conference (*L6*) was held in Sydney on 9-10 September 2010.[16]

On 1 February 2010, the Life and Longevity Markets Association (LLMA) was established in London. Its members were Aviva, AXA, Deutsche Bank, J.P. Morgan, Morgan Stanley, Prudential (UK) PLC, and Swiss Re. LLMA was formed to promote the development of a liquid market in longevity- and mortality-related risks. This market is related to the ILS market and is also similar to other markets with trend risks, e.g., the market in inflation-linked securities and derivatives. LLMA aims to support the development of consistent standards, methodologies and benchmarks to help build a liquid trading market needed to support the future demand for longevity protection by insurers and pension funds. In April 2011, the LifeMetrics indices were transferred to LLMA with the aim of establishing a global benchmark for trading longevity and mortality risk.

In December 2010, building on its successful mortality catastrophe bonds and taking into account the lessons learned from the EIB bond, Swiss Re launched a series of eight-year longevity-based ILS notes valued at $50m. To do this, it used a special purpose vehicle, Kortis Capital, based in the Cayman Islands. As with the mortality bonds, the longevity notes are designed to hedge Swiss Re's own exposure to mortality and longevity risk. In particular, holders of the notes were exposed to an increase in the spread between mortality improvements in 75-85-year-old English & Welsh males and 55-65-year-old US males, indicating that Swiss Re has life insurance (mortality risk) exposure in the US and pension (longevity risk) exposure in the UK.

---

[14] The Index tracks the relationship between the accounting liability for retirees of a defined benefit pension plan and two cost measures: the estimated cost of transferring the pension liabilities to an insurance company (i.e., a buy-out) and the approximate total economic cost of retaining the pension obligations on the balance sheet.

[15] The conference proceedings for *L5* were published in the *North American Actuarial Journal* (Volume 15, Number 2, 2011).

[16] The conference proceedings for *L6* were published in the October 2011 issue of *Geneva Papers on Risk and Insurance - Issues and Practice.*

**2011: Longevity 7**

The seventh conference (*L7*) was held at the House of Finance, Goethe University, Frankfurt, Germany on 8-9 September 2011.[17]

In January 2011, the Irish government announced that it would issue bonds that allow the creation of sovereign annuities.[18] This followed a request from the Irish Association of Pension Funds and the Society of Actuaries in Ireland. If the bonds are purchased by Irish pension funds, this will have a beneficial effect on the way in which the Irish funding standard values pension liabilities. On account of a statutory deadline to submit a deficit repair plan, 2013 was a record year for bulk annuity transactions in Ireland with sovereign annuities being used in a significant number of transactions.

The world's first longevity swap for non-pensioners (i.e., for active and deferred members of a pension plan) took place in January 2011, when J. P. Morgan executed a £70m 10-year *q*-forward contract with the Pall (UK) pension fund. This was a value swap designed to hedge the longevity risk in the value of Pall's pension liabilities, rather than the longevity risk in its pension payments as in the case of cash flow swaps which have been the majority of the swaps that had so far taken place. Longevity risk prior to retirement is all valuation risk: there is no cash flow risk and most of the risk lies in the forecasts of mortality improvements. Further, the longevity exposure of deferreds is not well defined as a result of the options that plan members have, e.g., lump sum commutation options, early retirement options, and the options to increase spouses' benefits at the expense of members' benefits.

In April 2011, the International Society of Life Settlement Professionals (ISLSP)[19] formed a life settlement and derivatives committee and announced that it was developing a life settlement index. The purpose of the index was to benchmark net asset values in life settlements trading. Investors need a reliable benchmark to measure performance and the index will help turn US life insurance policies into a tradable asset class according to ISLSP. The calculation agent for the index was AA Partners.

The first pension risk transfers deals outside the UK took place in 2009-11. The first buy-in deal outside the UK took place in 2009 in Canada; it was arranged by Sun Life Financial and valued at C$50m. The first buy-in deal in Europe took place in December 2010 between the Dutch food manufacturer Hero and the Dutch insurer Aegon (€44m). The first

[17] The conference proceedings for *L7* were published in the September 2013 issue of the *Journal of Risk and Insurance*.

[18] A sovereign annuity, introduced by the 2011 Social Welfare and Pensions Act, is an annuity contract issued by insurance companies where the annual income payment is linked directly to payments under bonds issued by Ireland or any other EU member state (known as reference bonds). The payments can be reduced if there is an event of non-performance in relation to the bonds to which the annuity is referenced. This contrasts with a standard annuity where the insurer guarantees to make the agreed payments for the lifetime of the annuitant.

[19] www.islsp.org

buy-in deal in the US took place in May 2011 between Hickory Springs Manufacturing Company and PICA ($75m). The first buy-out deal outside the UK was announced in May 2011 and involved the C$2.5bn Nortel pension plan in Canada. In September 2011, CAMRADATA Analytical Services launched a new pension risk transfer (PRT) database for US pension plans. The database provides insurance company organizational information, pension buy-in and buy-out product fact sheets and screening tools, pricing data, up-to-date information on each PRT provider's financial strength and relevant industry research. Users can request pension buy-in and buy-out quotes directly from providers, including American General Life Companies, MetLife, Pacific Life, Principal Financial Group, PICA, Transamerica and United of Omaha.

The first international longevity reinsurance[20] transaction took place in June 2011 between Rothesay Life (UK) and PICA and was valued at £100m. The first life book reinsurance swap since the 2007-08 Global Financial Crisis took place in June 2011 between Atlanticlux and institutional investors and was valued at €60m.

**2012: Longevity 8**

The eighth conference (*L8*) was held at the University of Waterloo, Ontario, Canada on 7-8 September 2012.[21]

In February 2012, Deutsche Bank executed a massive €12bn index-based longevity swap for Aegon in the Netherlands. This solution was based on Dutch population data and enabled Aegon to hedge the liabilities associated with a portion of its annuity book. Because the swap[22] was out of the money, the notional amount of longevity risk transferred (€300mn) was far less than that suggested by the headline €12bn figure. Nonetheless, the key driver for this transaction from Aegon's point of view was the reduction in economic capital it hoped to achieve. Most of the longevity risk was passed on to capital markets investors in the form of private bonds and swaps. The duration of the hedge was 10 years.

In June 2012, General Motors Co. (GM) in the US announced a huge deal to transfer up to $26bn of pension obligations to PICA. This is by far the largest ever longevity risk transfer deal globally. The transaction is effectively a partial pension buy-out involving the purchase of a group annuity contract for GM's salaried retirees who retired before 1 December 2011 and refused a lump sum offer in 2012. To the extent retirees accepted a lump sum payment in lieu of future pension payments, the longevity risk was transferred directly to the retiree.[23] The deal was classified as a partial buy-out rather than a buy-in because it involved the settlement of the obligation. In other words, the portion of the liabilities associated with the annuity contract will no longer be GM's obligation. Moreover, in contrast to a buy-in, the annuity contract will not be an asset of the pension plan, but instead an asset of the retirees. In October 2012, GM did a $3.6bn buy-out of the

[20] The insurance industry's name for a longevity swap.
[21] The conference proceedings for *L8* were published in the *North American Actuarial Journal* (Volume 18(1), 2014).
[22] It is structured as a bull call option spread – see Michaelson and Mullholland (2014).
[23] In fact, the lump sum was only being offered to limited cohorts of plan members.

pension obligations of its white-collar retirees. Also in October 2012, Verizon Communications executed a $7.5bn bulk annuity buy-in with PICA. The buy-out deals in the US in 2012 amounted to $36bn.

**2013: Longevity 9**

The ninth conference (*L9*) was held in Beijing, China on 6-7 September 2013.[24]

The first £1bn+ PRT in the UK took place in July 2013, when Citigroup executed a £1.5bn buy-out for its EMI Group Pension Fund with Pension Insurance Corporation (PIC), a specialist UK buy-out insurer, covering all 20,000 members.[25]

In February 2013, the first medically underwritten bulk annuity (MUBA) transaction was executed in the UK by the UK insurer Partnership.[26] This involved each member filling in a medical questionnaire in order to get a more accurate assessment of their life expectancy based on their medical history or lifestyle. This was particularly useful in the case of 'top slicing', where scheme trustees insure the pensioners (who will typically be the company directors) with the largest liabilities and who therefore represent a disproportionate risk concentration for the scheme. In December 2014, Partnership executed a £206m medically underwritten bulk annuity transaction with a 'top slicing' arrangement for the £2bn Taylor Wimpey pension scheme. UK insurer Legal & General (L&G) transacted a £230m medically-underwritten buy-in in December 2015. The process of collecting medical information has been streamlined in recent years using third-party medical data collectors, such as MorganAsh, Age Partnership and Aon's AHEAD platform. It is expected that the share of medically underwritten de-risking deals will increase significantly over the next few years in the UK, with new business more than doubling from £540m in 2014 to £1,200m in 2015.[27]

In April 2013, L&G reported its first non-UK deal, the buy-out of a €136m annuity book from New Ireland Life. In June 2013, the Canadian Wheat Board executed a C$150m pension buy-in from Sun Life of Canada, involving inflation-linked annuities, while in March 2014, an unnamed Canadian company purchased C$500m of annuities from an insurer (reported to be Industrial Alliance), making it the largest ever Canadian pension risk transfer deal to date.

In August 2013, Numerix, a risk management and derivatives valuation company, introduced a new asset class called 'life' on its risk modeling platform (in addition to equities, bonds and commodities). In November 2013, SPX Corp. of Charlotte, NC, purchased a buy-out contract with Massachusetts Mutual Life Insurance Co. (MassMutual) as part of a deal that moved $800m in pension obligations off SPX's balance sheet.

[24] The conference proceedings for *L9* were published in July 2015 in *Insurance: Mathematics and Economics* 63(C): 1-203.
[25] https://www.professionalpensions.com/news/2280322/emi-scheme-agrees-recordbreaking-gbp15bn-buyout
[26] Harrison and Blake (2013).
[27] Hunt and Blake (2016).

In September 2013, UK consultant Barnett Waddingham launched an insurer financial strength review service which provides information on an insurer's structure, solvency position, credit rating, and key risks in their business model. This service was introduced in response to concerns about the financial strength of some buy-out insurers.

In November 2013, Deutsche Bank introduced the Longevity Experience Option (LEO). It is structured as an out-of-the-money call option spread on 10-year forward survival rates and has a 10-year maturity. The survival rates will be based on males and females in five-year age cohorts (between 50 to 79) derived from the England & Wales and Netherlands LLMA longevity indices. LEOs will be traded over-the-counter under a standard ISDA[28] contract. They allow longevity risk to be transferred between pension funds, insurance companies and investors. They are intended to provide a cheaper and more liquid alternative to bespoke longevity swaps which are generally costly and time consuming to implement. Purchasers of the option spread, such as a pension fund, will gain if realized survival rates are higher than the forward rates, but the gains will be limited, thereby providing some comfort to the investors providing the longevity hedge. The 10-year maturity is the maximum that Deutsche Bank believes investors will tolerate in the current stage in the development of a market in longevity risk transfers. It was reported that Deutsche Bank executed its first LEO transaction with an ILS fund in January 2014.

In December 2013, Aegon executed a second risk transfer to capital markets investors and reinsurers, including SCOR. The €1.4bn index-based hedge involved Dutch longevity risk and US mortality risk, had a notional value of €200m and a duration of 20 years. Société Générale was the intermediary in the deal and Risk Management Solutions (RMS) was the modelling agent.

Also in December 2013, the Joint Forum reported on the results of its consultation on the longevity risk transfer market. It concluded that this market is not yet big enough to raise systemic concerns, but 'their massive potential size and growing interest from investment banks to mobilize this risk make it important to ensure that these markets are safe, both on a prudential and systemic level' (Joint Forum (2013, p.2)).

**2014: Longevity 10**

The tenth conference (*L10*) was held at Universidad Diego Portales in Santiago, Chile on 3-4 September 2014.[29]

In February 2014, the Mercer Global Pension Buy-out Index was introduced. It shows the benchmark prices of 18 independent third-party insurers in the four countries with the greatest interest in buying out DB liabilities: UK, US, Canada and Ireland. Costs were highest in the UK where the cost of insuring £100m of pension liabilities was 123% of the

[28] International Swaps and Derivatives Association; https://www.isda.org/
[29] The conference proceedings for L10 were published in the *Journal of Risk and Insurance*, Volume 84, Number S1, April 2017, 273-532.

accounting value of the liabilities – equivalent to £32 per £1 p.a. of pension.[30] The comparable costs in Ireland, the U.S. and Canada were 117%, 108.5% and 105%, respectively. The higher cost in the UK is in part due to the greater degree of inflation uprating in the UK compared with the other countries. The difference between the US and Canada is explained by the use of different mortality tables. Rising interest rates and equity markets will lower funding deficits and hence lead to lower buy-out costs in future, especially in the US.

In March 2014, L&G announced the biggest single buy-out in the UK to date when it took on £3bn of assets and liabilities from ICI's pension fund, a subsidiary of AkzoNobel. In December 2014, L&G announced the largest ever UK buy-in valued at £2.5bn with US manufacturer TRW. Around £13bn of bulk annuity deals were executed in the UK in 2014, the largest volume of business since the de-risking market began in 2006 and beating the previous best year of 2008, just before the Global Financial Crisis, when £7.9bn of deals were completed. The total volume of de-risking deals in the UK in 2014 (covering buy-outs, buy-ins and longevity swaps) was £35bn, a significant proportion of which is accounted for by the £16bn BT longevity swap.

In July 2014, Mercer and Zurich launched Streamlined Longevity Solution, a longevity swap hedge for smaller pension schemes with liabilities above £50m. This is part of a new Mercer SmartDB service which provides bespoke longevity de-risking solutions and involves a panel of reinsurers led by Zurich. It reduces the costs by having standardized processes for quantifying the longevity risk in each pension scheme. The first deal, valued at £90m, was transacted with an unnamed UK pension scheme in December 2015.

In August 2014, the Dutch insurer Delta Lloyd executed a six-year index-based longevity hedge with Reinsurance Group of America (RGA Re) with a notional value of €300m and providing partial cover on €12bn of liabilities.[31]

In November 2014, the Longevity Basis Risk Working Group (2014) of the Institute and Faculty of Actuaries (IFoA) and LLMA published 'Longevity Basis Risk: A Methodology for Assessing Basis Risk'. This study develops a new framework for insurers and pension schemes to assess longevity basis risk.[32] This, in turn, will enable simpler, more standardized and easier to execute index-based longevity swaps to be implemented. Index-based longevity swaps allow insurers and pension schemes to offset the systematic risk of increased liabilities resulting from members living longer than expected. It had hitherto

[30] Towers Watson (2015) *Corporate Briefing*, April.
[31] https://www.bloomberg.com/news/articles/2014-08-22/delta-lloyd-completes-16-billion-longevity-swap-with-rga
[32] According to the Institute and Faculty of Actuaries: 'Longevity basis risk arises because different populations, or subpopulations, will inevitably experience different longevity outcomes. This is a significant issue for those wishing to hedge longevity risk using a published mortality index – whether they be pension schemes, insurers, reinsurers, or banks'. The IFoA and Life and Longevity Markets Association have developed a readily-applicable methodology for quantifying the basis risk arising from the use of population-based mortality indices for managing longevity risk; https://www.actuaries.org.uk/learn-and-develop/research-and-knowledge/actuarial-research-centre-arc/recent-research/longevity-basis-risk

been difficult to assess how effectively an index-based longevity swap could reduce the longevity risk in a particular insurance book or pension scheme. The methodology developed in the report is applicable to both large schemes (which are able to use their own data in their models) and smaller schemes (by capturing demographic differences such as socio-economic class and deprivation).

In December 2014, Towers Watson launched Longevity Direct, an off-shore longevity swap hedging service that gives medium-sized pension schemes with liabilities between £1-3bn direct access to the reinsurance market, via its own cell (or captive) insurance company. This allows schemes to bypass insurers and investment banks, the traditional de-risking intermediaries, and significantly reduces transactions costs and completion times, while still getting the best possible reinsurance pricing. The first reported transaction on the Longevity Direct platform was the £1.5bn longevity swap executed by the Merchant Navy Officers Pension Fund (MNOPF) in January 2015 which was insured by MNOPF IC, a newly established cell insurance company based in the Channel Island of Guernsey, and then reinsured with Pacific Life Re. In February 2015, PwC launched a similar off-shore longevity swap service for pension schemes as small as £250m. It used a Guernsey-based incorporated cell company called Iccaria, established by Artex Risk Solutions, to pass longevity risk directly on to reinsurers. The arrangement is fully collateralized and each scheme owns a cell within Iccaria which again avoids the costs of dealing with insurer and investment bank intermediaries.

There is increasing demand from reinsurance companies for exposure to large books of pension annuity business to offset the risk in their books of life insurance.[33] For example, in 2014, Warren Buffett's Berkshire Hathaway agreed to a £780m quota-reinsurance deal with PIC.[34] Similarly, in August 2014, AXA France executed a €750m longevity swap with Hannover Re.

**2015: Longevity 11**

The eleventh conference (*L11*) was hosted by Université Lyon 1, Lyon, France on 7-8 September 2015.[35]

In March 2015, the UK government announced that it would introduce a new competitive corporate tax structure to allow ILS to be domiciled in the UK and the associated Risk Transformation Regulations 2017, creating a new regulated activity of insurance risk transformation, came into effect in December 2017. In May 2015, Rothesay Life, the insurance company owned by Goldman Sachs, bought out the liabilities of Lehman

[33] The key risk in life books, mortality risk (the risk that life policy holders die sooner than expected, so payouts are made before sufficient premiums have been collected), can be offset (at least partially) by assuming the longevity risk in annuity books (the risk that annuitants live longer than expected). If there is an unanticipated reduction in life expectancy, the increased payouts on the life book are offset by the reduced payouts on the annuity book, and vice versa. This is known as a 'natural hedge'.
[34] Reported in *Financial News*, 14 July 2014.
[35] The conference proceedings for *L11* were published in *Insurance: Mathematics and Economics*, 78 (2018), 157–380.

Brothers' UK pension scheme for £675m, thereby securing the pensions of former employees of the company associated with the beginning of the Global Financial Crisis. In April 2016, Rothesay bought two-thirds of Aegon's UK annuity book – representing 187,000 policy holders – for £6bn, bringing total assets under management to £20bn and total lives assured to over 400,000. This was the first substantial annuity transfer since the introduction of Solvency II[36] in January 2016. This new solvency regime for EU-based insurers increased capital requirements and has reduced the attractiveness of annuities as a business line for certain insurers and raised buy-out prices by 5-7%.[37]

In 2015, L&G entered both the US and European pension risk transfer markets. It executed a $450m transaction with the US subsidiary of Royal Philips covering 7,000 scheme members in October and a €200m deal with ASR Nederland NV, a Dutch insurer in December. The pension obligations were transferred to L&G Re in cooperation with Hannover Re. L&G said: 'The pension risk transfer market has become a global business…The potential market for pension risk transfer in the US, UK and Europe is huge, and will play out over many decades'. Two US insurers were also involved in the Royal Philips deal: PICA also acquired $450m of scheme liabilities covering another 7,000 members, while American United Life Insurance Company issued annuity contracts to 3,000 deferred scheme members, valued at $200m.

In January 2015, the Bell Canada Pension Plan executed a C$5bn longevity swap with Sun Life Financial,[38] SCOR, and RGA Re; it was SCOR's first transaction in North America. In the process, Canada became the first country apart from the UK to have all three pension risk transfer solutions actively in use. In the same year, it completed its first inflation-linked buy-in annuity transaction, while in 2017, it completed its first buy-in annuity covering active future benefits.[39] In June 2015, Delta Lloyd did a second €12bn longevity swap with RGA Re: the swap was also index-based, with an 8-year duration and had a notional value of €350m.[40] In July 2015, Aegon executed one valued at €6bn with Canada Life Re, a new entrant to the de-risking market in 2015. Another new entrant was Scottish Widows.

In June 2015, the Mercer Pension Risk Exchange was launched. It gives clients in the US, UK and Canada up-to-date buy-in and buy-out pricing based on their plan's data. It collects prices provided monthly by insurers in the bulk market, based on plan benefit structures and member data. Mercer said: 'Many companies have the appetite to transfer pension risk off their balance sheet, but they face barriers: lack of clear information about the true cost of a buy-in or buy-out, limited transparency, the fluctuation of market rates and plan economics to name but a few. [The exchange will enable] sponsoring employers and trustees to be more strategic and sophisticated in their approach and to know that they are executing a buy-in or a buy-out at the best time for them and at a competitive price'.

---

[36] https://www.eiopa.europa.eu/browse/solvency-2_en and https://en.wikipedia.org/wiki/Solvency_II
[37] *Financial News*, 28 March–3 April 2016.
[38] Sun Life Financial uses the RMS Longevity Risk Model, which RMS describes as a 'structural meta-model of geroscience advancement'.
[39] Eckler Consultants (2017) *Pension Risk Transfer Report*, November.
[40]http://www.artemis.bm/blog/2015/06/26/delta-lloyd-rga-in-second-e12-billion-longevity-swap-deal/

**2016: Longevity 12**

The twelfth conference (*L12*) was held in Chicago on 29-30 September 2016 and hosted by the Society of Actuaries and the Pensions Institute.[41]

In April 2016, Willis Towers Watson (WTW[42]) released PulseModel which uses medical science and the opinions of medical experts to improve longevity predictions. For example, the model predicts that 16% of 50-year-old men in the UK will develop type-2 diabetes in the next 20 years, but this rises to 50% for those who are both obese and heavy smokers. Overall, the model predicts that longevity improvements in the future will be lower than currently predicted, at around 1% p.a. rather than 1.5%. If this turned out to be correct, then the current price of longevity of risk transfer products would be overestimated.

The largest buy-in in 2016 (in December) was Phoenix Life's £1.2bn buy-in for the 4,400 pensioners in the PGL Pension Scheme, which is sponsored by the Phoenix Group, Phoenix Life's parent company. This replaced a longevity swap that it had set up for the plan in 2014. This is the first example of a transaction which transforms a longevity swap into a bulk annuity. Phoenix Life saw this as an opportunity to bring £1.2bn of liquid assets (mostly UK government bonds) onto its balance sheet, which could then be swapped into a higher yielding, matching portfolio, structured to maximize the capital benefit under Solvency II. This, in turn, meant that Phoenix Life would be assuming the market risks associated with the PGL scheme pension liabilities in addition to the longevity risks – and already does this on its existing book of individual annuities which are backed by £12bn of assets. The timing was also critical. Phoenix wanted to ensure that its internal model under Solvency II had bedded down well and that the capital and balance sheet impacts of the transaction were well understood, and that Phoenix had elicited the full support of the UK Prudential Regulation Authority (PRA)[43] for the transaction, thereby ensuring execution certainty. Phoenix also provided comfort to the plan's trustees by giving them 'all-risks' cover from point of buy-in ('all-risks' cover is not usually provided until buy-out) and strong collateral protection.[44]

2016 saw the beginning of a trend towards consolidation amongst insurance companies involved in the longevity risk transfer business in the UK. In April 2016, the two largest UK medical underwriters, Partnership and Just Retirement merged to form the Just Group valued at £16bn. Aegon sold its £9bn UK annuity portfolio to Rothesay Life and L&G between April and May, as part of a strategy to free up capital from non-core businesses. Part of the reason for this is the additional capital requirements under Solvency II. In September, Deutsche Bank sold its Abbey Life subsidiary to Phoenix Life – a consolidator of closed insurance books – for £935m, as part of a planned program of disposals aimed at restoring its capital base. There is an estimated £100bn of UK individual annuities in back

[41] The conference proceedings for *L12* were published in volume 25(S1) of the *North American Actuarial Journal* in 2021.
[42] The Willis Group and Towers Watson merged in 2016 to form WTW.
[43] This is the regulatory authority for insurance companies in the UK.
[44] Stephanie Baxter (2017) How PGL's longevity swap was converted into a buy-in, *Professional Pensions*, 10 April.

books and further consolidation of these back books is anticipated. In December 2017, L&G sold its £33bn closed book of traditional insurance-based pensions, savings and investment policies to the ReAssure division of Swiss Re for £650m.

Solvency II has also been blamed for some companies pulling out of the bulk annuities market altogether, a key example being Prudential (UK) in January 2016. Prudential (UK) announced it would be selling a portion of its £45bn UK annuity and pension liability businesses due to an inadequate return on capital and to transfer that capital to its growing businesses in the Far East.[45] Reinsurance deals have also increased in response to Solvency II, involving non-EU reinsurers. For example, PIC executed a £1.6bn longevity reinsurance agreement with PICA in June 2016.

2016 also witnessed the increasing streamlining and standardization of contracts. This is particularly beneficial to small plans below £100m. Previously, smaller plans have been less attractive to insurers due to the higher costs of arranging such deals relative to the profit earned. To circumvent this, consultants have begun offering services that allow smaller plans to access improved pricing and better commercial terms using a standardized off-the-shelf process incorporating pre-negotiated legal contracts. Pricing is more competitive because the insurer's costs are kept low. An example is WTW's Streamlined Bulk Annuity Service. The increasing maturity of the market has meant that some larger plans have also been prepared to use pre-negotiated contracts.

2016 was also the tenth anniversary of the longevity transfer market. Since its beginning in the UK in 2006, £40bn of buy-outs and £31bn of buy-ins have taken place in the UK, covering one million people.[46] Yet this equates to just 5% of the £1.5trn of UK DB pension assets and 3% of the £2.7trn of DB pension liabilities on a buy-out basis in 2016. In addition, forty eight longevity swaps are known to have been completed in the United Kingdom between 2007 and 2016, valued at £75bn and covering 13 insurance companies' annuity and buy-out books, 22 private sector pension funds, and one local authority pension fund (some of which executed more than one swap).[47]

**2017: Longevity 13**

The thirteenth conference (*L13*) was held in Taipei, Taiwan on 21-22 September 2017. It was hosted by the Department of Risk Management and Insurance and the Risk and Insurance Research Center at National Chengchi University, and by the Pensions Institute.[48]

At the beginning of 2017, there were eight UK-domiciled insurers actively participating in the pension risk transfer market in the UK. The largest players were PIC and L&G, with

[45] https://www.ftadviser.com/pensions/2016/12/05/prudential-seeks-buyers-for-45bn-annuity-business/
[46] LCP, *Professional Pensions* (15 December 2016 and 26 January 2017). Since 2007, some 92 buy-ins have been completed.
[47] www.artemis.bm/library/longevity_swaps_risk_transfers.html.
[48] The conference proceedings for *L13* were published in volume 25(S1) of the *North American Actuarial Journal* in 2021.

market shares of 37% and 30%, respectively. The others were Rothesay Life, Canada Life, Zurich, Scottish Widows, Standard Life, and new entrant Phoenix (since August). Occasionally, the insurers co-operate in a transaction. To illustrate, in August 2017, L&G executed a longevity swap in respect of £800m of the pension liabilities of Scottish and Southern Energy (SSE), while PIC completed a £350m buy-in for the company. Consultant LCP estimated that £12bn buy-ins and buy-outs took place in 2017 and £19bn took place in 2018, with total insurer capacity at £25bn: 'There remains significant capacity and competition – even if a large back-book comes to market – providing attractive opportunities for pension plans to transfer longevity risk through a buy-in or buy-out'.[49]

One of the largest deals in 2017 (in September) involved a £3.4bn longevity swap between the Marsh & McLennan Companies (MMC) UK Pension Fund and both Canada Life Re and PICA, using Guernsey-based incorporated cell companies, Fission Alpha IC Limited and Fission Beta IC Limited. MMC subsidiary Mercer led the transaction as adviser to the pension fund trustee and the deal was the first to be completed using the Mercer Marsh longevity captive solution, with no upfront premium. The two reinsurers shared the risk equally and the use of the captive ICC vehicle meant that no insurer intermediary was required, making the deal more cost-effective for the pension fund.[50] Also in September, the British Airways' Airways Pension Scheme used a similar Guernsey-based captive insurer to set up a £1.7bn longevity swap. The longevity risk was then reinsured with Partner Re and Canada Life Re. The scheme had previously hedged £2.6bn of liabilities through two longevity swap transactions executed by Rothesay Life in 2010 and 2011.[51] In November 2017, PIC executed a £900m longevity swap with PICA, while in December 2017, L&G executed a £600m longevity swap with PICA.[52]

In December 2017, NN Life, part of the Nationale-Nederlanden Group, the largest Dutch insurance company, executed an index-based longevity hedge with reinsurer Hannover Re, in a deal covering the insurer against the longevity trend risk in €3bn of its liabilities (the notional value was €100m). The intermediary was Longitude Solutions, run by Avery Michaelson and David Schrager. The hedge structure is similar to the 2013 Aegon tail-risk deal arranged by Société Générale and builds on subsequent work including Michaelson and Mulholland (2014) and Cairns and El Boukfaoui (2021). While the term of the transaction is 20 years, NN Life is protected over a longer time period via a commutation function[53] that applies at maturity. If longevity improvements have been much stronger

[49] https://www.lcp.uk.com/media-centre/press-releases/2017/08/buy-in-and-buy-out-volumes-nearly-double; LCP (2018) *Pension De-risking 2018*.

[50]http://www.artemis.bm/blog/2017/09/14/mmc-pension-offloads-huge-3-4bn-of-longevity-risk-to-reinsurers. The counter to this cost-effectiveness is that the hedger takes on additional counterparty risk. If a reinsurer fails then there is no insurer to protect MMC's pension scheme.

[51] Nick Reeve (2017) BA scheme uses 'captive insurer' in £1.6bn longevity risk hedge, *IPE*, 13 September.

[52] https://www.pensioncorporation.com/media/press-releases/Prudential, PIC Reach $1.2 Billion Longevity Reinsurance Agreement; L&G reinsures £600m of longevity risk through Prudential, *Professional Pensions*, 21 December 2017.

[53] The role of the 'commutation function' is to 'compress' the risk period. As explained in Michaelson and Mulholland (2014, pp.32-33): 'This is accomplished by basing the final index calculations on the combination of two elements: (1) the actual mortality experience, as published by the national statistical reporting agency, applied to the exposure defined for the risk period; and (2) the present value of the

than expected, this will be assumed to continue until the liabilities run-off and NN will receive a payment under the hedge. The transaction helped to reduce the solvency capital requirement of NN's Netherlands life business by €35m. The index attachment point for the hedge is close to NN's best estimate, which helps maintain the SCR (Solvency Capital Requirement)[54] relief and effective risk transfer over time.[55, 56]

In order to reduce the costs of de-risking, pension plans are encouraged to perform some liability reduction exercises, the key ones being:[57]

- Enhanced transfer values (ETVs) – allow deferred members to transfer an uplifted value of their benefits to an alternative arrangement. In August 2017, a 64-year old entitled to an annual index-linked pension starting at £10,000 from age 65 would be offered a transfer value of £237,000, according to the Xafinity Transfer Value Index.[58] In October 2019, the transfer value was £244,200. In 2019, around 50,000 members transferred out of their DB scheme, around 1% of eligible members.[59]
- Flexible retirement options (FROs) – allow deferred members aged 55 and over to retire early, or to take a transfer value and secure benefits in a different format from their plan benefits, or to use funds for drawdown purposes.
- Pension increase exchanges (PIEs) – allow pensioners to exchange non-statutory increases for a higher immediate pension with lower or even zero future increases (e.g., a £10,000 annual pension with inflation uplifting is replaced by a £12,000 annual pension with no further increases).
- Trivial commutations (TCs) – allow members with low value benefits to cash these in.

The most common exercises currently in the UK are PIEs and TCs – and these can be conducted either before or at the same time as a bulk purchase annuity broking exercise. Hymans Robertson has estimated that the use of these liability reduction exercises could reduce the buy-out cost for UK DB schemes by around £100bn or 6% of total liabilities.[60]

Innovation is a continuing feature of this market. Some examples include (see, e.g., Legal & General and Engaged Investor, 2016):[61]

---

remaining exposure at the end of the risk period calculated using a 're-parameterized' longevity model that takes into account the realized mortality experience over the life of the transaction'.

[54] The SCR is the amount of funds that insurance and reinsurance companies are required to hold under Solvency II in order to have a 99.5% confidence they could survive the most extreme expected losses over the course of a year. The SCR incorporates market, credit, operational and counterparty risks, and must be recalculated at least once per year; https://www.risk.net/definition/solvency-capital-requirement

[55] http://www.artemis.bm/blog/2017/12/01/nn-life-gets-index-based-longevity-hedge-from-hannover-re/

[56] https://www.nn-group.com/Investors/Capital-Markets-Day-2017.htm

[57] *Professional Pensions* (2016) Risk reduction and the extent of trust in pension scheme advisers and providers, June, p.26.

[58] Hannah Godfrey (2017) DB transfer values back on the rise in August, *Professional Adviser*, 7 September.

[59] Sophie Smith (2019) DB transfer values in record fall – XPS, *Pensions Age*, 7 November.

[60] https://www.ipe.com/news/uk-roundup-clear-member-options-could-reduce-buyout-db-costs-by-100bn/10060598.article

[61] Legal & General and Engaged Investor (2016) *De-risking Journeys of Mid-sized Pension Schemes*, June.

- Buy-ins and buy-outs with deferred premium payments – to spread costs, schemes that cannot afford the upfront premium of a de-risking solution pay for it in instalments over a number of years.
- Buy-outs combined with a longevity hedge.[62]
- Phased buy-ins, where the largest risks or the lowest cost risks are insured first.
- Phased de-risking using a sequence of partial buy-ins with an 'umbrella' structure to avoid more than one set of contract negotiations – to spread costs.
- Accelerated buy-ins – the insurer provides a loan to the plan equal to the deficit (sometimes called a winding up lump sum (WULS)), so that a partial buy-in can take place immediately, with this converting to a full buy-in when the loan has been repaid, or with the option of a full buy-out at a later date.
- Forward start buy-ins – a standard buy-in with the start date delayed to reflect the level of funding available, with additional options, such as paying deferred members as and when they retire if this is prior to the start date, or the ability to bring forward the start date for an additional fee.
- Self-managed buy-ins – which allows pension schemes to run their own asset management strategy at lower cost and with a lighter regulatory burden than if an insurer was involved (introduced in 2018 by the UK asset manager Insight Investment). The strategy uses swaps to hedge interest, inflation and longevity risks and is estimated to be 10-15% cheaper than the equivalent insurance product.[63]
- Automated bulk plan transfers – to reduce risks (introduced in November 2017 by Scottish Widows and Standard Life).[64]
- Top-slice buy-ins – to target the highest value liabilities.
- Named-life longevity swap – if the named member lives longer than expected, the insurer pays out the difference (examples being the £400m Bentley plan and an unnamed plan with 90 named pensioners valued at £50m).
- Tranching by age – to reduce costs; according to consultant Punter Southall, a buy-in for pensioners up to age 70 will make a subsequent buy-out within the following 10 years cheaper than a buy-in for the over 70s.[65]
- Longevity swaps for small pension plans with liabilities of £50-100m – previously only available for medium (£100-500m) and large plans (above £500m).
- Novation – the ability to transfer a longevity hedge from one provider to another, thereby introducing some liquidity into what had previously been a completely illiquid market. An example would be the reinsurance of a small bulk annuity transaction. Contract simplicity is a desirable feature of such arrangements.

---

[62] An example of this was the Philips Pension Fund which in 2015 completed a full buy-out valued at £2.4bn with PIC. The longevity risk was simultaneously reinsured with Hannover Re. Another interesting feature of this deal was that it covered both retired and deferred members.

[63] Angus Peters (2018) Insurers compete with fund managers for lucrative pension pots, FTfm, 15 January. The article points out that 'insurers and asset managers are engaged in a turf war for the £1.6tn sitting in the UK's defined benefit schemes'.

[64] Michael Klimes (2017) How the first automated bulk scheme transfers happened, *Professional Pensions*, 10 November.

[65] James Phillips (2017) DB schemes insuring wrong tranche of members in buy-ins, *Professional Pensions*, 14 August.

- Longevity swap to buy-in conversions – as pioneered by Phoenix Life in December 2016 for its parent company's pension plan. Solvency II incentivizes buy-in providers to hold longevity insurance, otherwise they pay an additional risk margin. This encourages buy-in providers to seek out plans which already have a longevity hedge and encourage them to do a buy-in. Another driver is longevity swap providers that are not currently active in the market – such as J.P. Morgan and Credit Suisse – but are still responsible for running off their existing swaps. They might have an incentive to encourage the associated pension plan to novate the swap to a buy-in provider and hence extinguish their liability.[66]
- Insuring away the extreme tail of liabilities in a closed plan after a specified term, such as 5 or 10 years – to reduce costs.
- Increasing optionality in contracts to improve flexibility – for example, the option to switch the indexation measure for pensions in payment from the Retail Price Index to the Consumer Price Index if government legislation changes; or the option to secure discretionary benefits, such as actual inflation above a 5% cap; or surrender options.
- Insuring the tail of the liabilities – whereby a closed scheme that cannot afford a full buy-out insures only the liabilities after a certain point in time, say, 10 years' ahead.
- Combining liability management solutions (such as interest rate and inflation swaps, and ETV, FRO and PIE exercises) and bulk annuities in a buy-out – so instead of completing liability management before considering a buy-out, plans do this in a single exercise.
- 'Buy-out aware' investment portfolios – used to reduce buy-out price volatility and close the funding shortfall, with the buy-out price locked to the value of the buy-out aware funds once a target shortfall has been reached and whilst the contract documentation for a buy-out is being completed.
- Improved arrangements for handling data errors that arise after a deal has been executed – to reduce pre-deal negotiation requirements and post-deal transaction uncertainty. Common data errors include member gender, date of birth, and benefit amounts for both member and partner. A simplified data error process could deal with these issues in the following way: locking down benefits, removing the need for re-pricing; mechanistically adjusting demographic errors; and using due diligence to check for systematic errors with the data.[67]
- Residual risk insurance, covering, e.g., benefit specification errors, data errors, and unidentified beneficiary cover.
- Arrangements to handle deferred members – to improve insurer appetite to assume the additional risk and cost involved. Deferred lives make up almost half (45%) of the membership of UK DB plans in the UK.[68] They are much more expensive to

[66] Stephanie Baxter (2017) Converting longevity swaps into bulk annuities: The next de-risking innovation?, *Professional Pensions*, 13 April.
[67] Andrew Murphy (2017) Developments in longevity swaps, Pacific Life Re, 23 November, IFoA Life Conference. Provided due diligence has been carried out at the outset, subsequent data errors tend to be unbiased in terms of their impact and so average out close to zero.
[68] That is 4.9m members (The Pension Regulator and the Pension Protection Fund, *Purple Book 2015*).

hedge for a number of reasons. First, there can be problems with their existence and identification. Second, they enjoy a large number of options which need to be priced.[69] Third, their longevity risk is greater, because the longevity improvement assumption used for pricing has greater reliance on the assumed long-run trend.[70] Fourth, as a direct consequence of the previous points, more capital is needed and this, in turn, increases the demand for reinsurance. These issues can be at least partially mitigated as follows: a robust existence checking procedure is needed involving electronic tracing, assuming a fixed percentage of the pension is exchanged for tax-free cash, setting the assumed retirement date to the plan's normal retirement date, assuming no pension is exchanged for additional partner pension, restricting the age profile to older deferred members, and restricting the proportion of deferred members in the transaction.[71]

These are all innovations in the space linking pension plans and insurance companies designed to ease the transfer of pension liabilities (or at least the longevity risk in them) from pension plans to insurance companies.

The innovations have helped to encourage more business, but this, in turn, has exposed potential longer term capacity constraints within insurance companies. As one consultant said: 'Given the market has historically completed only 150-200 deals in any one year, there is a real risk of capacity constraints in the market, not just from an insurer capital perspective, but also from a resource and expertise perspective'.[72]

A total of £12.4bn in buy-ins and buy-outs and £.6.4bn in longevity swaps took place in the UK in 2017.

In April 2015, the UK government introduced 'Freedom and Choice' pension reforms which gave more flexibility to how individuals could draw down their defined contribution (DC) pension pots.[73] In particular, there was no longer a requirement to purchase an

[69] For example, lump sum commutation, trivial commutation, early/late retirement, increasing a partner's benefits at the expense of the member's benefits, and pension increase exchanges.

[70] Valuation and risk assessment of a deferred annuity can be broken down into five overlapping components: survival to retirement; the socio-economic group of the pensioner at the date of retirement; the base mortality table at the time of retirement for that socio-economic group; general mortality improvements (e.g., age 65+) up to the date of retirement; and the mortality improvement rate after retirement. Uncertainty in the probability of survival to retirement will typically be quite small in relation to the other risks.

[71] Andrew Murphy (2017) Developments in longevity swaps, Pacific Life Re, 23 November, IFoA Life Conference.

[72] Martyn Phillips, Mercer (quoted in *Professional Pensions* (2016) Risk Reduction and the Extent of Trust in Pension Scheme Advisers and Providers, June, p.28). Hannover Re had previously warned about this: 'The number of risk-takers is limited and there is no unlimited capacity in the market for taking on longevity risk. The increasing worldwide demand for longevity cover will challenge the capacity for securing longevity risk' (quoted in Punter Southall (2015) *De-risking Bulletin*, March). At the time, there were significant human resource bottlenecks in some parts of the transaction chain, in particular, a shortage of qualified lawyers.

[73] The proposal was announced by the UK finance minister (George Osborne) in his Budget Speech on 19 April 2014.

annuity.[74] This immediately led to a fall in annuity sales by around 75% (Cannon et al (2016)). The situation was not helped by the fall in gilt (UK government bond) yields (which led to a corresponding fall in annuity rates) arising from the government's quantitative easing program introduced after the Global Financial Crisis. In August 2017, a 65-year old with a £100,000 pension pot, could get a level income for life of £4,894: two years before, the amount would have been £5,292.[75] By 2017, the following insurers had pulled out of the open market for annuities: Aegon, LV=, Partnership (before it merged with Just Retirement to form Just Group), Prudential (UK), Standard Life, Friends Life (merged with Aviva), Reliance Mutual, B&CE, and Retirement Advantage. This left just six providers in what was once the world's largest annuity market: Aviva (offering standard and enhanced (i.e., medically underwritten) annuities), Canada Life (standard and enhanced), Hodge Lifetime (standard only), Just Group (enhanced only), L&G (standard and enhanced) and Scottish Widows (standard and enhanced).[76]

In place of annuities, individuals took their pension pot either as a lump sum or they purchased an income drawdown product. In both cases, they bear their own longevity risk. Evidence shows that people systematically underestimate their life expectancy which implies that there is a significant probability that many people will spend their pension pot before they die. A study by Just Group found that UK men aged 40-54 expect to live until 78.9 years on average, whereas the official estimate of their life expectancy is 87.5; the figures for women are 80.5 and 90.1.[77]

A number of UK insurers providing bulk annuities for buy-ins are also involved in the UK equity release mortgage (ERM, or reverse mortgage or lifetime mortgage) market which allows home owners to borrow against the equity in their homes. The modern form of the market began when the Equity Release Council (ERC) representing providers was established in 1991 with a voluntary code of conduct that offered a number of guarantees. Before this, users of the product could lose their homes when the value of the loan plus interest exceeded the value of the property. Since 1991, there is a guaranteed right to remain living in the property, either for life or until entry into long-term care. In addition, there is a 'no negative equity guarantee' (NNEG)[78] which means that the value of the loan plus interest can never exceed the value of the property, and so no debt can be passed on to the estate of the equity release borrower. The providers in the new market therefore face longevity risk in a way that those in the old market did not. In 2017, a total of £3bn in equity release loans were made with an average size loan of £102,000. In 2018, the UK Prudential Regulation Authority (2018) raised concerns that providers were not properly reflecting the cost of the NNEG in their capital reserving. Instead of valuing the NNEG

[74]https://www.pensionsadvisoryservice.org.uk/about-pensions/pension-reform/freedom-and-choice
[75] Josephine Cumbo (2017), Pensioners hit as annuity rates drop 10% in two years, *Financial Times*, 1 September.
[76] *Source: Hargreaves Lansdown, August 2017. Scottish Widows introduced a standard annuity in September 2019.*
[77] Chris Seekings (2018) Millions of Brits underestimating their life expectancy by a decade, *The Actuary*, 3 May. There were similar findings in a study by the Institute for Fiscal Studies, see James Phillips (2018) New retirees overly pessimistic about life expectancy, *Professional Pensions*, 17 April.
[78] See Dowd et al. (2019).

using the Black (1976) model as a series of put options on the forward house price (which is lower than the current price to reflect the loss of rental income due to deferred possession) weighted by the probability of mortality, morbidity and pre-payment, it pointed out that most providers were using the expected future house price which required assumptions about property growth.

There were also important developments outside the UK in 2017, although many of these involve innovations adopted from the UK market. Apart from the US, Canada, and the Netherlands, new markets include Germany, Switzerland and Ireland. Examples of innovations in the US include: plan-specific mortality data – with $250m as the minimum transaction size; asset-in-kind premium funding – where bonds are used to fund the transaction. Insurer capacity has also increased, with 14 insurers engaged in pension buy-outs. Three new insurers joined: Athene,[79] Mutual of America, and CUNA Mutual. Athene wrote more than $2bn of business in 2017. A total of $24.7bn pension risk transfers were conducted in the US in 2017. In Canada, group annuity sales amounted to C$3.7bn, and a new group annuity provider, Brookfield Annuity, joined the market. In Germany, many schemes were considering using lump sum settlement payments to pensioners to transfer longevity risk. In Switzerland, insurers are now willing to consider transfers involving active members. In Ireland, Danske Bank transferred €335m of its Irish DB pension liabilities to Irish Life.[80]

In April 2017, the International Monetary Fund (IMF) released a new edition of its *Global Financial Stability Report*. Chapter 2 ('Low Growth, Low Interest Rates, and Financial Intermediation') suggests that DB pension funds across the globe might have to cut benefits 'significantly' in the long term because of ultra-low interest rates. Attempts to increase returns by changing asset allocations 'appears feasible only by taking potentially unacceptable levels of risk'. In the face of such low rates, the IMF argues that 'life insurers and pension funds would face a long-lasting transitional challenge to profitability and solvency, which is likely to require additional capital' or would require a 'very high' level of volatility risk to meet their funding goals. However, a combination of risk aversion and regulatory constraints was likely to deter the vast majority from taking this second path. The IMF instead believes that the current situation might work to the benefit of insurers backing buy-ins and buy-outs. With investors increasingly monitoring the size of DB liabilities and the effects on company share prices, profits, and dividends, the IMF said offloading these liabilities to insurers 'is an attractive option' and 'may represent a market-efficient arrangement' and that 'regulation could play an important role in this area by facilitating such transactions'.

[79] Athene is majority owned by private equity company Apollo Global Management, LLC.
[80] Navigating you through your de-risking journey: Overseas, *Aon Risk Settlement Market Review 2018*.

**2018: Longevity 14**

The fourteenth conference (*L14*) was held in Amsterdam on 20-21 September 2018. It was hosted by the Pensions Institute and the Netspar Network for Studies on Pensions, Aging and Retirement.[81]

2018 saw the start of a trend towards consolidation amongst pension schemes in the UK. This was led by a group of private equity investors. One example is the Pension Superfund which was launched in March with £500m in seed capital provided by Edi Truell's Disruptive Capital and Warburg Pincus. Another example is Clara-Pensions which has £500m in seed capital from TPG Sixth Street Partners. Both have set up as occupational pension scheme master trusts. Antony Barker of the Pension Superfund predicted that if the UK follows the experience of the Dutch and the Australian markets, consolidation could lead to the 5,500 UK DB schemes being reduced to 1,500 by the end of the decade. He argued that, while many will go into insurance buy-outs and another 50-100 insolvent schemes could end up in the Pension Protection Fund (PPF),[82] this leaves potentially 2,000 that could end up with a superfund. That could represent £800bn in assets out of a total of £1.8trn in UK DB pension assets.[83]

The business models of the two consolidators are different, however. Clara-Pensions takes over the obligations and risks from pension scheme sponsors, but then becomes a 'bridge to a buy-out'. Its shareholders do not see a return on capital until every member has their full benefits secured in the insured market. In the meantime, it will need to hedge these risks, including longevity risk. By contrast, the Pension Superfund operates as a long-term run-off scheme. But instead of being supported by an operating company covenant, as in a standard occupational pension scheme trust, it is supported by a financial covenant in the form of a partnership holding material financial commitments from the former sponsor and new external capital providers, that should ensure members get at least 99% certainty of receiving their promised benefits in full. Any surplus of assets above 115% of liabilities 'on a prudent actuarial basis' will be shared one-third to members and two-thirds to the investors. The liabilities would be hedged and the investment strategy would be 'fairly low risk'. The Pension Superfund planned to use reinsurance through a captive model in due course. It would be initially targeting schemes with assets between £200m-£1bn with a strong sponsor covenant.[84]

---

[81] The conference proceedings for *L14* were published in volume 14(2) of the *Annals of Actuarial Science* in 2020.

[82] The Pension Protection Fund is a statutory fund in the UK which takes on the assets and liabilities of the defined benefit schemes of UK companies that have become insolvent. Any member who is over their normal retirement age or who retired early due to ill health will receive 100% of their current pension. Other members will receive 90% of their pension entitlement at the time of insolvency up to a cap. The sponsors of all eligible schemes must pay a levy to the PPF. See https://www.ppf.co.uk/

[83] Quoted in Mona Dohle (2020) Superfunds - New entrants to the DB consolidation market, *Portfolio Institutional*, 17 August.

[84] Adam Saron, Chief Executive Officer, Clara-Pensions, and Antony Barker, Managing Director, The Pension Superfund, interviewed in *Longevity Trends 2020*, published by Longevity Leaders, January 2020. See also Willis Towers Watson *De-risking Report 2020*, January (p.24).

Insurers have expressed concerns that, since such pension consolidation vehicles come under the Pensions Regulator (TPR) (i.e., are classified as pension schemes), they do not have to satisfy the much stricter solvency requirements of insurers which are regulated by the Prudential Regulation Authority, which is part of the Bank of England.[85] Both the Pension Superfund and Clara-Pensions aim to undercut insurance buy-out pricing by up to 10-15%.[86] The two consolidators justify themselves as filling a gap between a full insurance buy-out and schemes entering into the PPF following the insolvency of their sponsor. Each year, around 2% of the UK's 5,500 schemes either buy-out or enter the PPF. The consolidators offer a solution to solvent companies that cannot afford a full buy-out. Insurers have responded to the challenge from the consolidators by offering these companies access to an investment and hedging strategy that moves them closer to the goal of a full buy-out or buy-in. The Pension Superfund agreed two deals in 2019, but these have been delayed due to an absence of regulatory approval and the government was at the time still considering an authorization, supervision and solvency regime.[87] An interim regime for superfunds was introduced in June 2020. In November 2021, Clara-Pensions became the first superfund to complete TPR's assessment process and meet its 'tough new standards' of governance and administration. It appointed Kempen Capital Management as fiduciary manager and Hymans Robertson as scheme administrator.[88]

The General Data Protection Regulation (GDPR) was introduced in all EU member states in May 2018 and will affect longevity risk transfers since they involve the exchange of personal data. There are fines for data protection breaches. The GDPR distinguishes between data controllers – people who determine how and why data should be used – and data processors – who process data on behalf of data controllers. Pension scheme trustees will be data controllers, as will insurers if they have received personal data in connection with a potential buy-out transaction (e.g., if they are conducting a data cleansing or medical underwriting exercise). In other cases, insurers might be classified as data processors. International data transfers, e.g., in the case where an insurer wants to transfer data to a reinsurer located outside the European Economic Area, can only take place if adequate data protections are in place. Care needs to be taken even if anonymized data is transferred, since it might still be possible to identify the individuals to whom the data relates, e.g., company directors might be identified from information about the size of their pension benefits and date of birth.

[85] James Phillips (2018) The Pension Superfund to split surplus with members and capital providers, *Professional Pensions*, 12 July.
[86] *Superfunds: New solutions for DB pension plans?*, KPMG, August 2018; https://assets.kpmg/content/dam/kpmg/uk/pdf/2018/08/kpmg-superfunds-solutions-for-db-pension-plans.PDF
[87] Nick Reeve (2019) Pension Super Fund signs up second client in £300m deal, *IPE*, 30 July; James Phillips (2019) Clara: 'Shadow market' is huge for DB consolidation, *Professional Pensions*, 22 October. The government passed a Pension Schemes Act in February 2021, but it did not contain legislation for a DB consolidator regime.
[88] https://www.pensionsage.com/pa/BREAKING-Clara-Pensions-becomes-first-TPR-assessed-DB-superfund.php

For 2018, the key highlights in the UK longevity risk transfer market were:[89]

- PIC reinsured all its pensioner liabilities (73% of its total exposure) with Partner Re in January. It also helped to fund University Partnerships Programme acquisitions of student accommodation with index-linked bonds in February.
- Scottish Widows executed a £1.3bn longevity swap with PICA in February.[90] It was the last UK insurer to hedge at least some of its longevity risk. It did this to reduce its Solvency II capital requirements.
- Standard Life Aberdeen sold £2.93bn of its annuity back-book to Phoenix in February, with the rest of Standard Life Assurance sold to Phoenix in September.
- Prudential (UK) sold £12bn of its annuity back-book covering 400,000 policies to Rothesay Life in March, making Rothesay the UK's largest specialist annuity insurer with more than £37bn of assets and 750,000 lives insured.[91]
- In March, the Marks & Spencer Pension Scheme executed two buy-ins totalling £1.4bn with Aviva and Phoenix covering 15% of its pension liabilities. It was Aviva's largest buy-in to date (at £925m) and Phoenix's first external buy-in (at £475m).
- In March, PIC and PICA introduced a 'flow reinsurance'[92] system which automates the longevity reinsurance element of buy-outs and buy-ins for schemes with

[89] There were £24.2bn of transfers (buy-outs and buy-ins) in the UK in 2018 plus another £7bn in longevity swaps. The biggest insurers in the market were L&G, PIC, Zurich, Scottish Widows, Aviva, Canada Life, Just, Phoenix Life, and Rothesay Life (*LCP De-risking Report 2020*).

[90] Since 2011, PICA has completed more than £32bn in international reinsurance deals, including the £16bn deal with the BT Pension Scheme in 2014.

[91] In August 2019, the High Court in London blocked the Prudential-Rothesay transfer on the grounds that Rothesay was a 'relatively new entrant without an established reputation in the business' and although it had solvency ratios at least equal to Prudential's, 'it does not have the same capital management policies or the backing of a large group with the resources and a reputational imperative to support a company that carries its business name if the need were to arise over the lifetime of the annuity policies' (Susanna Rust (2019) High Court blocks £12bn Prudential-Rothesay annuities transfer, *IPE*, 19 August). In September 2019, Prudential and Rothesay announced that they would appeal against the decision on the basis that the judgement 'contains material errors of law' and should be reconsidered. On 2 December 2020, the Appeal Court granted an appeal against the High Court decision to block the Prudential to Rothesay Life transfer, on the grounds that the High Court had not given adequate weight to analysis by industry bodies and conclusions by the Prudential Regulation Authority and the Financial Conduct Authority, neither of which objected to the transfer. The issue of whether to sanction the scheme would be passed to the High Court for a second hearing. In November 2021, the High Court approved the transfer of the £12bn portfolio of annuities from Prudential (now a subsidiary of M&G) to Rothesay Life.

[92] Rupal Mepani, Head of BPA transactions, Hymans (12 August 2024): 'Flow reinsurance uses pre-arranged treaties which enable the insurer to transfer longevity risk on a quota share of new business quickly and efficiently and provides insurers with price certainty. With the increased focus at the smaller end of the market, more and more insurers are making use of flow treaties. Whether that's putting new arrangements in place or by renegotiating terms of their existing treaties to increase individual deal limits and/or total volumes that the insurer can write. Many insurers have made it clear that they do want to support the smaller pension schemes in the market. They are doing this by streamlining their pricing process allowing them to reallocate/optimise resources to unleash the value that comes with small schemes. Flow reinsurance treaties fit well to support this goal'; https://www.hymans.co.uk/insights/reinsurance-developments-in-the-bulk-purchase-annuity-market

liabilities below £200m. The system allows PIC to secure a commitment from PICA to assume the longevity risk early on in a transaction.[93]

- In March, employee benefits consultant, JLT, launched a 'buy-out comparison service' and monitoring tool which allows schemes to upload their own data and receive regular bulk annuity quotations from eight insurers currently active in the market.
- In April, JLT became the first consultant to implement Club Vita's longevity analytics capabilities which have been incorporated into RiskFirst's PFaroe modelling system for DB plans. This will allow JLT clients to set best-estimate longevity assumptions.[94] Club Vita data shows that pension schemes can have a very different demographic composition compared with the national population, with liabilities that could be up to 10% higher or lower as a result of different mortality experience.
- PIC executed a £900m longevity swap with PICA in May, covering 7,500 pensioners.[95]
- In June, Canada Life sold its £2.7bn back book of 155,000 UK life and pension savings policies to Scottish Friendly. The company said it wanted to concentrate on developing new retirement products following its acquisition of Retirement Advantage, an annuity and retirement income specialist, in January.
- Siemans completed a £1.3bn buy-in of its UK pension liabilities covering 6,000 members with PIC in July.
- Aviva executed a £1bn longevity swap with PICA in August.
- National Grid Electricity Group completed a £2bn longevity swap with Zurich[96] for the Electricity Supply Pension Scheme also in August.
- In August, L&G entered the small scheme longevity insurance market after completing a £300m longevity swap with an unnamed pension fund. The deal had a 'streamlined structure' with simplified data requirements which helped to keep fixed costs down. The swap was later reinsured with SCOR. According to L&G, 'the transaction demonstrates that longevity reinsurance is a realistic option for most pension schemes, including for trustees whose schemes are not quite at the point they can enter into buy-in or buy-out, but want to manage their longevity risk'.
- In September, the British Airways' Airways Pension Scheme entered into the UK's largest buy-in agreement to date (at £4.4bn) with L&G, covering 60% of pensioner liabilities; taking account of the £1.7bn longevity swap agreed in 2017, the scheme has now hedged 90% of its longevity risk.
- The Automobile Association Pension Scheme completed a £351m buy-in with Canada Life also in September.

---

[93] https://www.artemis.bm/news/prudential-pic-in-flow-longevity-reinsurance-deal-for-smaller-pensions/

[94] Club Vita is a longevity data analytics company which pools data from over 220 UK DB schemes covering 2.8m pensioners, approximately one quarter of the total. RiskFirst is a fintech company which launched the PFaroe software in 2009 to enable pension funds to manage their asset and liability risks.

[95] This brought the total value of all the deals between the two companies to £4.4bn.

[96] Zurich reinsured a significant proportion of the longevity risk with Canada Life Re. It has executed £3.5bn longevity risk transfer deals since it entered the market in 2016.

- In October, the UK pension scheme of Nortel, the Canadian telecoms company which became insolvent in 2009, agreed a £2.4bn buy-out deal with L&G, covering 15,000 pensioners and 7,200 deferred members, thereby avoiding entering the Pension Protection Fund.
- In December, PIC executed another longevity swap, this time with SCOR, covering 8,000 pensioners and valued at £1.2bn.[97]

In April 2018, the PRA said it was concerned that too much longevity risk was being transferred offshore through reinsurance arrangements, preferring that more of it be retained in the UK. It said it would consider amending Solvency II risk charges to encourage greater retention. While it said it understood the need for risk transfer, it said that it was concerned that pension assets were being transferred overseas, taking them outside of its regulation, so that if an offshore reinsurance firm failed, UK pensioners might not get their pensions.[98]

The first ever longevity swap in the US was executed by RGA in 2018. In Canada, the Life Insurance Capital Adequacy Test (LICAT) regulations came into effect at the start of 2018. RGA redesigned a longevity transaction structure to create two LICAT-compliant cash flow swaps which transferred longevity risk but not investment risk, and improved capital efficiency for both parties[99]

**2019: Longevity 15**

The fifteenth conference (*L15*) was held in Washington DC on 12-13 September 2019. It was hosted by the Pensions Institute.[100]

A total of £43.8bn longevity risk transfer deals were announced for the UK in 2019.[101] XPS reported that for a buy-out for a medium-sized scheme, pensioner member transfers

[97] This brought the total value of the deals between the two companies to £2.2bn.
[98] Steve Evans (2018) Bank of England wants more longevity risk retained, less reinsured, *Reinsurance News*, 27 April; https://www.reinsurancene.ws/bank-of-england-wants-more-longevity-risk-retained-less-reinsured/
[99] https://www.rgare.com/docs/default-source/investor-relations/rga_ar18.pdf
[100] The conference proceedings for *L15* were published in 2021 in *Insurance: Mathematics and Economics*, 99(C): 130-508.
[101] *LCP De-risking Report 2020*. This compares with £1bn when the market started in 2006. The eight insurance companies involved were: Rothesay Life (37% market share), L&G (24%), PIC (16%), Aviva (9%), Phoenix Life (9%), Scottish Widows (5%), Just (3%), and Canada Life (1%). Their total assets and asset allocations are given below. In terms of transaction volumes, 65% of deals were over £1bn, 29% of deals were between £100m and £1bn, and 6% of deals were below £100m.

*Total assets and asset allocations of the main UK PRT providers 2019*

| | L&G | Rothesay Life | Aviva | PIC | Scottish Widows | Just | Canada Life | Phoenix Life |
|---|---|---|---|---|---|---|---|---|
| Total assets (£bn) | 75.9 | 53.7 | 46 | 40.9 | 22 | 21.6 | 18.7 | 11.7 |
| Government bonds & cash (%) | 72 | 47 | 14 | 44 | 30 | 57 | 61 | 28 |

used a 'gilts + 0.3% p.a.' discount rate to value the liabilities (i.e., technical provisions), while for deferred members the discount rate was 'gilts – 0.5% p.a.'.[102] Willis Towers Watson reported an average buy-in price at 0.15% p.a. above gilts.[103]

Highlights included:

- In January, PIC invested £125m in Exeter University accommodation in order to generate index-linked cash flows to pay its pensioners.
- In the same month, PIC completed a £425m buy-in with the Co-operative Group's Somerfield Pension Scheme.
- L&G executed buy-ins with the Pearson Pension Plan (£500m in February), Howden Group Pension Plan (£230m in March) and 3i Group (£95m in April).
- Rothesay completed a buy-in (amount undisclosed) with the Teachers Assurance Group Pension Scheme in February, and a £110m buy-out with the Laird Pension Scheme in April.
- Also in April, PIC completed a £1.2bn buy-in with Commerzbank in respect of the Dresdner Kleinwort Pension Plan of its UK subsidiary. This involved three transactions. The first was a £900m buy-in of the DB section. The second and third involved the DC section and gave members of the hybrid scheme the option of transferring their DC pension out or convert it into a DB equivalent for transfer to PIC.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Corporate bonds (%) | | 14 | 29 | 53 | 30 | | | 44 |
| Equity release/lifetime mortgages (%) | 6 | 5 | 16 | 3 | 40 (alternative credit investments) | 37 | 6 | 23 |
| Commercial mortgages and healthcare (%) | - | - | 16 | - | | - | 8 | - |
| Secured Lending and residential mortgages (%) | - | 25 | - | - | | - | - | - |
| Infrastructure (%) | - | 9 | 17 | - | - | 4 | - | - |
| Private placement and structured finance | - | - | 4 | - | - | 2 | - | 5 |
| Direct investments (%) | 22 | - | - | - | - | - | - | - |
| Real estate (%) | - | - | - | - | - | - | 5 | - |
| Other (%) | - | - | 4 | - | - | - | - | - |
| Source: LCP *De-Risking Report 2020* | | | | | | | | |

[102] *XPS Risk Transfer News*, 10/19.
[103] Figure 2 in Willis Towers Watson *De-risking Report 2020*, January.

- In May 2019, the British American Tobacco UK Pension Fund completed a £3.4bn buy-in with PIC, the second-largest buy-in to date.
- Also in May, PIC and Phoenix insured £900m and £460m, respectively, of the liabilities of Marks & Spencer's UK pension scheme.
- In June, Rolls Royce executed the biggest buy-out to date – at £4.6bn – with L&G, covering the benefits of 33,000 pensioners. As part of the deal, a longevity swap originally with Deutsche Bank was transferred to L&G – the first time a swap has been novated between counterparties.
- In July, Scottish Widows completed buy-ins totalling £830m with Peugeot and QinetiQ
- In August, PIC executed a £3.4bn de-risking deal with the British American Tobacco UK Pension Fund covering both 8,300 pensioners and 2,300 deferred members. It is the biggest deal to date covering both retired and non-retired members.
- In August, PICA completed a £7bn longevity swap with banking group HSBC's UK pension scheme – making it the second largest swap in the UK after the £16bn swap for the British Telecom Pension Scheme in 2014, also arranged by PICA. The transaction – which covers half of the scheme's pensioner liabilities – was structured as an insurance contract with a Bermuda-based, HSBC-owned captive insurer, which reinsured the longevity risk with PICA. It was the first captive longevity reinsurance transaction for a pension scheme associated with a major bank. Amy Kessler, PICA's head of longevity risk transfer, said: 'The captive approach has become the strategy of choice for large pension schemes seeking to hedge longevity risk'.[104]
- In August, Phoenix Life completed a £1.1bn buy-in of its own DB pension scheme, the PGL Pension Scheme. In the same month, it executed a longevity reinsurance arrangement with PICA.[105]
- In August, Rothesay Life executed a £520m buy-in with the Cadbury Mondelēz Pension Fund, covering 1,900 pensioner members.
- In August, L&G announced it had completed a buy-in transaction for the UK hybrid pension scheme of data and technology company Hitachi Vantara. The deal was described as 'innovative' since it also took into account the DC elements of the scheme. Each member's retirement benefit is based on the higher of the DB and DC pension over their career with Hitachi Vantara. The buy-in was structured to maintain this arrangement, allowing deferred members to 'consider their options' prior to a full buy-out.[106]
- In September, L&G arranged a £930m buy-in with the Tate & Lyle Pension Scheme, covering 4,800 members.
- In September, Rothesay Life executed an even larger buy-in than the Rolls Royce deal in June – at £4.7bn – with the GEC 1972 Plan, covering 39,000 members split 70-30 between pensioners and deferreds. There is an option for a buy-out at a later

[104] Susanna Rust (2019) HSBC pension scheme strikes £7bn longevity risk transfer, *IPE*, 6 August.
[105] https://www.artemis.bm/news/prudential-in-longevity-reinsurance-deal-for-pension-insurer-phoenix/
[106] Nick Reeve (2019) L&G backs 'innovative' buy-in for Hitachi UK pension scheme, *IPE*, 14 August.

date. Hence this is known as a 'buy-in to buy-out deal'. The parent company of GEC is Telent.

- Also in September, Rothesay Life insured £3.8bn of members' benefits for the Allied Domecq Pension Fund in another buy-in covering around 27,000 pensioners and deferred members, spilt 63-37. The parent company of Allied Domecq is the Pernod Ricard Group.
- In October, Rothesay completed a £2.8bn buy-in with the National Grid Pension Scheme (Section A). The following month, L&G completed a £1.6bn buy-in with the National Grid Pension Scheme (Section B), covering 6,000 pensioner members.
- In October, Rothesay executed a full buy-in with retailer ASDA (owned by Walmart) for £3.8bn, covering 4,800 pensioners and 7,500 deferred members. This converted to a full buy-out in 2020-21 at an additional cost of £800m.
- In October, Aviva Life and Pensions UK completed a £1.7bn buy-in for the Aviva Staff Pension Scheme, covering 1,500 pensioners and 4,300 deferred members.
- In November, Phoenix completed a £144m buy-in with the Aegon UK Staff Retirement and Death Benefit Scheme.
- In December, Zurich and Hannover Re completed a £800m longevity swap with an unnamed FTSE100 company.

Other UK developments in 2019 included:

- In February, L&G launched Track My Apps, a tracking service provided by fintech company Origo, to enable advisers to track their clients pension transfers online.
- £936m of equity release deals in the first quarter with 20,000 households, taking out an average of £50,000 in housing wealth.
- In May, L&G announced the creation of a UK retirement housing business called Guild Living which plans to deliver 3,000 new homes over the next five years with a gross development value of £2bn.[107] The business will contribute the income it needs to pay the benefits on its longevity risk transfer business. In August, L&G announced it had acquired a site in Walton-on-Thames suitable for building 300 homes.
- In June, L&G launched the first pension risk transfer execution platform to be driven by blockchain technology. Known as 'Estua-Re', the technology provides a 'single ecosystem capable of driving every stage of the PRT reinsurance value chain', including pricing, claims handling, financial reporting, and collateral. It allows multiple parties to transact with each other without the need for an intermediary and there will be greater transparency since all parties will have access to the latest version of the ledger database.[108]
- In August, PICA and the Phoenix Group launched a reinsurance counterparty to provide longevity reinsurance for insurers in the UK pension risk transfer market, covering both their buy-out and buy-in transactions. Phoenix head of bulk annuities Justin Grainger said: 'Phoenix views longevity reinsurance as a key risk

[107] https://www.legalandgeneralgroup.com/media-centre/press-releases/legal-general-launches-guild-living-bringing-retirement-communities-to-uk-city-centres/

[108] https://www.professionalpensions.com/news/3077264/-deploys-blockchain-technology-streamline-pension-reinsurance

management tool. This transaction brings further depth to our reinsurer relationships and enhances our ability to offer competitive terms to pension schemes as we continue to develop our de-risking proposition'. Prudential Financial head of international transactions for longevity risk transfer Rohit Mathur said: '[PICA] has consistently focused on supporting the entire UK pension de-risking market. The addition of Phoenix is a culmination of our efforts over the past several years to do just that. We have invested in our pricing and transaction teams and …and we are happy to be in a position to support the robust pipeline of pension buy-ins and buy-outs seeking to be completed while market conditions hold'. PICA was advised in this deal by Willkie Farr & Gallagher, while Phoenix was advised by CMS and Eversheds Sutherland.[109]

- In September, Rothesay announced it would raise an additional £500m in shareholder capital to support its longevity risk transfer business – which in 2019 alone executed around £10bn in new deals.
- In November, L&G agreed to provide annuities to Prudential (UK) customers with guaranteed rates. As part of the deal, all guaranteed benefits will be honoured by Prudential (UK) and fulfilled by L&G. As mentioned above, Prudential (UK), while remaining a UK-registered company, is closing down its UK operations in order to grow its businesses in the Far East.
- In November, PIC converted a £800m longevity swap – originally executed in 2017 with L&G – for a £750m buy-in for Scottish & Southern Energy (SSE) on the back of improved funding for the pension scheme. This is the first example of a transfer of obligations between counterparties where the first counterparty (L&G) could have offered the buy-in itself. In novating the swap between counterparties, it is another important milestone in bringing an early form of liquidity to the longevity swaps market. The first conversion of a longevity swap to buy-in took place in 2016 (by Phoenix Life) and the SSE conversion is the fifth one to date. PIC said that a longevity swap provides a useful first step towards a buy-in.[110]
- In November, Scottish Friendly bought the back book of Canada Life's 127,000 life and pensions policies, with assets under management increasing by £2.4bn as a result.
- There was a modest recovery in annuity sales following the big fall in sales after the 'Freedom and Choice' reforms of 2015. There were 74,000 (internal and open market) annuity purchases in 2018/19. Annuity rates for 65-year olds were 4%, which although low by historical standards, exceeded the 3% that a lower-risk fund recommended as a sustainable withdrawal rate.[111]

There were a number of reasons explaining the strength of the UK longevity risk transfer market in 2018 and 2019. First, funding levels had improved as a result of deficit reduction contributions and strong equity returns, which increased asset values, and lower liability

[109] Holly Roach (2019) PICA launches reinsurance counterparty to back UK bulk annuities, *Professional Pensions*, 5 August.
[110] Susanna Rust (2019) Energy scheme completes rare longevity swap to buy-in conversion, *IPE*, 13 November.
[111] Greg Nielson (2019) Glimmers of an annuity market renaissance, *Retirement Planner*, 7 November.

values due to a combination of higher interest rates and lower mortality improvements since 2011;[112] UK funds exhibited the first surplus in aggregate since 2011.[113] Second, there was an increase in capital and competition from insurers which had recruited heavily and so had more staff to model pension scheme mortality, provide price quotations and implement transactions. Third, was an associated increase in reinsurance capacity, which is important since most of the longevity risk assumed by insurers is reinsured with global reinsurers. Fourth, there had been increasing standardization of the frameworks used to execute transfers, with three dominant examples: intermediated, pass through, and captive. Fifth, insurers had been increasing their investment in high yielding illiquid matching assets, such as infrastructure, housing and urban regeneration, and equity release, and had passed on the additional yield (including illiquidity premium) to schemes in the form of lower prices. Sixth, greater certainty over how Solvency II reserving requirements operate had helped to reduce margins for prudence. Finally, once a scheme closes to new entrants, its maturity increases rapidly: the proportion of the scheme's liabilities due to pensioners increases and the average age of non-pensioners also increases. Mature schemes tend to attract more favourable pricing because: scheme data for pensioners tend to be more reliable than for other types of member, there is less uncertainty over the timing and size of future cash flows, and the risk of the actual mortality experience deviating from that which was assumed is lower. All this helped to reduce the capital an insurer is required to hold.[114] Mercer has estimated that by 2030 more than £600bn of longevity risk transfers will have taken place in the UK, which represents around one-third of UK pension fund assets.[115]

Outside the UK, some significant developments took place in 2019, including:

- A longevity swap by RGA Life Reinsurance Company of Canada, covering 45,000 Manulife Canadian annuitants (February).
- A longevity swap by PartnerRe, covering 25,000 Manulife annuitants (March and May).
- A €5.5bn longevity swap by Canada Life Re, covering 150,000 in-payment and deferred pensioners liabilities of Dutch firm VIVAT (March).
- A €12bn longevity swap by Canada Life Re, for Dutch insurer Aegon, covering 200,000 in-payment and deferred pensioners (December).[116]
- There were also some significant buy-outs and buy-ins, e.g., PICA's $1.8bn buy-out of the Lockheed Martin pension scheme and a C$200m buy-in with an unnamed

[112] This is discussed later.

[113] At the end of November 2018, aggregate pension assets were £1.58trn, while aggregate pension liabilities were £1.57trn on a section 179 basis, according to the Pension Protection Fund's *Purple Book*. Some 3,008 schemes had a combined deficit of £137.6bn, while 2,442 schemes had a combined surplus of £151.9bn. During the previous 10 years, FTE100 companies had paid £82bn into their DB schemes in order to reduce their deficits (which equals one-eighth of the £636bn they paid out in dividends). If companies doubled their annual pension contributions to £16.6bn, 30% of schemes could buy-out their pension liabilities in 5 years, and 70% in 10 years (Kim Keveh (2019) Half of FTSE100 DB schemes could buy-out within 10 years, finds Barnett Waddingham*, Professional Pensions*, 1 July).

[114] Attractive pricing opportunities for buy-in/buy-out, XPS Pensions, *Briefing Note No. 2*, June 2018.

[115] Mark Cobley (2019) Pension insurance deals to top £600bn by 2030, says Mercer, *Financial News*, 16 December.

[116] https://www.artemis.bm/news/aegon-gets-e12bn-longevity-reinsurance-cover-from-canada-life-re/

Canadian scheme executed by Brookfield Annuity Company and reinsured by L&G; this was L&G's first transaction in Canada.

- LifeXcel, a trading platform for mortality-linked contracts (MLCs), such as life settlements, was established in the US for institutions and hedge funds only. LifeXcel is an alternative assets administration company, specializing in structuring, distributing, and managing portfolios of MLCs. In 2021, the platform opened to 'accredited investors' in the US.

**The introduction of third-party capital**

We had mentioned earlier the problem of capacity constraints in the insurance and reinsurance industries. Our conference series is explicitly about capital markets solutions to the problem of transferring longevity risk. When the modern form of the longevity risk transfer market started in 2006, investment banks, such as J.P.Morgan, with their links to capital market investors, became active in the market along with insurers. However, the Global Financial Crisis in 2007-08 and the 2010 US Dodd-Frank (Restoring American Financial Stability) Act which followed led to the majority of investment banks withdrawing from the market. A few banks with insurance subsidiaries – such as Goldman Sachs, owner of Rothesay Life, and Deutsche Bank, owner of Abbey Life – remained for a while before they too sold their life businesses. So for the past few years, the market has been dominated by insurers and reinsurers. However, they are beginning to see that the current growth rates in the market are not sustainable without new sources of external (or third-party) capital.

One new solution to this problem that has emerged recently is the reinsurance sidecar – which is a way to share risks with new investors when the latter are concerned about the ceding reinsurer having an informational advantage. Formally, a reinsurance sidecar is a financial structure established to allow external investors to take on the risk and benefit from the return of specific books of insurance or reinsurance business. It is typically set up by existing (re)insurers that are looking to either partner with another source of capital or set up an entity to enable them to accept capital from third-party investors (Bugler et al. (2021)).

It is established as a special purpose vehicle (SPV), with a maturity of 2-3 years. It is capitalized by specialist insurance funds, usually by preference shares, though sometimes in the form of debt instruments. It reinsures a defined pre-agreed book of business or category of risk. Liability is limited to the assets of the SPV and the vehicle is unrated. The benefit to insurers is that sidecars can provide protection against exposure to peak longevity risks,[117] help with capital management by providing additional capacity without the need for permanent capital, and can provide an additional source of income by leveraging underwriting expertise. The benefit to investors is that they enjoy targeted non-correlated returns relating to specific short-horizon risks and have an agreed procedure for exiting; investors can also take advantage of temporary price hikes, but without facing legacy issues that could affect an investment in a typical insurer.

[117] That is, specific individual cashflows that give rise to the greatest uncertainty in value terms.

There are a number of challenges to the use of sidecars in the longevity risk transfer market. There is the tension between the long-term nature of longevity risk and investor preference for a short-term investment horizon. There are also regulatory requirements on cedants, affecting their ability to generate a return. These include: the posting of prudent collateral, the underlying assets in the SPV must generate matching cash flows, the risk transfer must be genuine, and the custodian/trustee must be financially strong. There is also a risk to cedants of losing capital relief if regulatory requirements are not met or they change.

Three reinsurance sidecars were established at the end of 2017 and the beginning of 2018, with investment capital provided by private equity investors and hedge funds, in addition to insurers and pension funds.

In December 2017, Athene entered into a reinsurance agreement with Voya Financial, covering $19bn of fixed, indexed and variable annuity liabilities. The matching assets will be managed by Athene Asset Management. By using an 'enhanced asset management' strategy and positioning itself for 'incremental value creation in a more favorable credit spread environment', the company hopes to generate 'mid-teens returns'. The capital is supplied mainly by private equity investors, including Apollo – Athene's parent company – Crestview Partners and Reverence Capital Partners.[118]

In January 2018, RGA Re and RenaissanceRe, announced a new start-up named Langhorne Re, which will target in-force life and annuity business. The new company has secured $780m of equity capital from RGA, RenaissanceRe and third-party sidecar investors, including pension funds and other life companies.[119]

In February 2018, the $400m Leo Re Ltd 2018-1 collateralized reinsurance sidecar was established between Dutch pension fund manager PGGM and Munich Re as a private ILS deal. The agreement allows PGGM, which manages the pension assets of the Dutch healthcare workers' scheme, PFZW, to gain access to a share of Munich Re's portfolio. PGGM will enter into direct ILS trades with counterparties, via quota share arrangements with a reinsurer, for a proportion of the counterparties' underwriting book, thereby sharing in the cedents' risks and underwriting returns.[120]

By 2021, more than $20bn in third-party capital from sidecar investors had been deployed to support around $400bn worth of life and annuity book transfers. There are three categories of transactions. The first is standard spread business, like pension risk transfer, fixed annuities, and fixed indexed annuities. The second focus on mortality risk for

[118] Athene & Apollo get long-term capital in $19bn annuity reinsurance deal, by Artemis on December 21, 2017; http://www.artemis.bm/blog/2017/12/21/athene-apollo-get-long-term-capital-in-19bn-annuity-reinsurance-deal/

[119] Steve Evans (2018) Langhorne Re launched by RGA and RenRe as in-force life and annuity reinsurer, *Reinsurance News*, 11 January,

[120] PGGM's $400m Leo Re is a private sidecar deal with Munich Re, by Artemis on February 5, 2018; http://www.artemis.bm/blog/2018/01/02/pggm-secures-140m-leo-re-sidecar-tranche-takes-2018-issue-to-400m/

inclusion in the same sidecar as annuity risk, thereby offsetting longevity and mortality risks in a capital-efficient way.[121] The third is variable annuities which is a more specialist category. The first category is the most common, while the third is the least. Sidecar platforms which cover all three categories include: Atlas Merchant Capital, Berkshire Hathaway, J. C. Flowers & Co, and Varge Agam. Sidecar investors include pension funds (e.g., APG, Canada Pension Plan, Ontario Teachers Pension Plan, PGGM), asset managers (e.g., Blackstone, Invesco, PIMCO), sovereign wealth funds (e.g., Abu Dhabi Investment Authority, NZ Super Fund), private equity and hedge funds (e.g., D. E. Shaw & Co, KKR), ILS funds (e.g., Leadenhall Capital Partners, Securis Investment Partners), endowments and family offices.[122]

In July, the Channel Island of Guernsey announced it would develop a simplified structure for the ILS market via an all-in-one legal entity that would combine insurance/reinsurance and investment activity in one vehicle – described as a 'Fund of One'. This would create a more transparent vehicle for investors which would promote 'true convergence' in ILS. Investors would establish both an unregulated investment fund and a reinsurance transformer cell. This would remove the need for multiple vehicles and allow a sidecar to have both the risks and the assets held in a single vehicle. This would help to reduce the challenges often associated with multiple vehicles, such as doing business in various jurisdictions, regulation, time zones, account rules, audit, and multiple layers of administration expenses.[123]

Another example of introducing new third-party capital is an initial public offer (IPO). This was the route Swiss Re considered in June 2019 when it proposed listing the shares of ReAssure – its UK closed book life consolidator business – on the London Stock Exchange. The idea was to provide working capital to put into new transactions and grow the UK life insurance book under the SwissRe brand. However, the idea was shelved due to weak demand and, in December 2019, ReAssure was sold to Phoenix for £3.2bn. In the process, Phoenix – which was valued at the time at £5.3bn – became Europe's biggest consolidator of life and pension businesses and justified the acquisition on the grounds that 'there are too many insurance companies in a market which is consolidating..[and the acquisition will] give us the opportunity to capture significant cost and capital synergies'.[124]

In September 2019, the European Life Settlement Association launched the ELSA Master Agreement for Tertiary Transactions (MATT). The aim was to develop an industry standard purchase and sale agreement to make tertiary transactions more cost and time efficient – in a similar manner as the ISDA Master Agreement.[125]

---

[121] That is, exploiting the natural hedge in the insurer's balance sheet.
[122] Kessler (2021, Table 14).
[123] Guernsey targets "true convergence" via all in one ILS structure, by Artemis on July 24, 2018; http://www.artemis.bm/blog/2018/07/24/guernsey-targets-true-convergence-via-all-in-one-ils-structure/
[124] Matt Sheehan (2019) Swiss Re confirms ReAssure IPO is set for July, *Reinsurance News*, 14 June; https://www.reinsurancene.ws/swiss-re-confirms-reassure-ipo-is-set-for-july/. Louis Ashworth and Michael O'Dwyer (2019) Phoenix boss bows out with £3.2bn takeover of insurance rival ReAssure, *Daily Telegraph*, 7 December.
[125] https://www.derivsdocu.com/services/consultancy/What-is-an-ISDA-Master-Agreement/

**2020**

***Longevity risk transfers***

2020 was a near record year for the longevity risk transfer market in the UK at £55.8bn. LCP and Mercer reported that £31.7bn of buy-ins and buy-outs and £24.1bn of longevity swaps were completed during the year. L&G had a 24% market share, followed by Rothesay with 22%, Aviva and PIC both on 19%.[126]

One explanation was that bulk annuity pricing in 2020 fell slightly compared with 2019. Pensioner pricing was based on a 'gilts + 0.2% p.a.' discount rate to value liabilities (instead of 'gilts + 0.3% p.a.'), while the pricing of deferred pensioner liabilities was based on a 'gilts – 0.35% p.a.' liability (instead of 'gilts – 0.5% p.a.'). This implied that a buy-out for pensioners was cheaper than using gilts for pensioners in payment (equivalent to valuing liabilities on a gilts-flat basis).[127]

Highlights for 2020 in the UK included:

- In January, Securis Investment Partners announced that they had completed a capital market derisking deal – a longevity swaption – with a 'large well-known life risk carrier': 'we have taken structured longevity risk on a specific block of business. The transaction was structured as an indemnity derisking tool, i.e., without the use of any longevity indices, as a way to optimize the impact for our counterparty even further.. [It involved] a direct risk transfer to a Securis fund with no intermediary involved,…and was a first in terms of regulatory approval'.[128]
- In January, PIC said it would raise £750m in additional capital from existing investors to continue expanding its buy-out business. At the time, it managed £40.9bn on behalf of 225,000 pension scheme members.[129]
- Also in January, Pacific Life Re executed a £10bn longevity swap with three Lloyds Banking Group pension schemes – the second largest on record. The deal covers pensioner liabilities in the Lloyds Bank Pension Schemes No.1 and No.2 and the HBOS Final Salary Pension Scheme. The deal was structured as an insurance contract with Scottish Widows as the insurer and Pacific Life Re as the reinsurer.[130]
- In February, PIC agreed a £1.6bn buy-in with the Merchant Navy Officers' Pension Fund covering 14,000 members, in the process taking over a longevity swap that

[126] UK. Pension longevity risk transfers reach record-breaking £55.8bn in 2020,*Pension Policy International*, 19 March 2021.
[127] Nick Reeve (2020), Longevity and risk transfer: A booming market, *IPE*, February; *XPS Risk Transfer News,* 8/20.
[128] Email announcement from Luca Tres, 8 January 2020. See also Paul Fulcher and Luca Tres (2019) A capital management toolkit for life re/insurers, *InsuranceERM*, 14 March; https://www.insuranceerm.com/analysis/a-capital-management-toolkit-for-life-reinsurers.html
[129] Emily Horton (2020) Pension Insurance Corporation to raise £750m from backers, *Financial News*, 28 January.
[130] James Phillips (2020) Lloyds schemes agree £10bn longevity swap with Pacific Life Re, *Professional Pensions*, 29 January; Lloyds Banking Group pension schemes strike £10bn longevity swap, *IPE*, 29 January 2020.

the fund initially executed with Pacific Life Re in 2014, using a Guernsey captive cell insurance company arrangement offered by Willis Towers Watson. This is another example of the novation of a swap to an annuity.[131]

- In February, Aviva and PIC each completed a £1bn buy-in with the Co-operative Pension Scheme. The deal was completed using a pre-agreed 'umbrella contract' designed to support a quick and efficient continuous process, each one covering 7,000 members. In May, Aviva completed a £350m buy-in transaction with the Co-operative Scheme covering an additional 2,300 members.[132]
- In February, PICA executed a $6bn reinsurance transaction with Rothesay Life.[133]
- In February, the AIB Group UK Pension Scheme completed a £1.1bn de-risking transaction with L&G, comprising a £850m buy-in combined with a £250m assured payment policy (APP).[134] The APP hedges the scheme's investment risk by protecting against changes in asset yields, interest rates and inflation, giving the scheme increased surety of being able to reach a full buy-out over a planned timeframe.[135]

---

[131] Susanna Rust (2020) Merchant navy fund converts longevity swap to £1.bn buy-in, *IPE*, 19 February.
[132] Susanna Rust (2020) Co-op pension scheme insures more liabilities as PIC deal disclosed, *IPE*, 19 February. Aviva in £350m bulk annuity deal with Co-operative Pension Scheme, *Reinsurance News*, 14 May 2020.
[133] Ditto.
[134] An assured payment policy is an insurance policy that provides the pension scheme with protection against investment-related risks, such as changes in asset returns, interest rates and inflation It was developed by L&G. APPs:

- Provide a pre-agreed series of future payments, which may be fixed or inflation-linked.
- Similar in nature to a buy-in, with the crucial difference being that APPs do not vary with longevity risk or other demographic experience. Compared with bulk annuities, they will be cheaper by around 15-20% for deferred pensioner members, but will be more expensive for pensioner members.
- Held as a pension scheme asset.
- Can apply to any sub-set of a pension scheme's liabilities.
- Can be used in combination with other de-risking solutions, such as pensioner buy-ins.

APPs can best be thought of as:

- Partial insurance: an APP locks down investment risk now, with a clear structure for adding the remaining pension-related risks in the future to 'complete the bulk annuity'; or
- An investment: an APP allows a pension scheme to 'build its own bond', with tailored inflation coverage and no exposure to market and reinvestment risk, while achieving a yield in excess of gilts.

APPs work as follows:

- An APP's fixed or inflation-linked pre-agreed payments are designed to match all or some of a pension scheme's liabilities.
- The trustees pay an upfront premium, as per a bulk annuity. In exchange, a payment schedule is agreed at outset, and payments are made by the provider to the trustees of the pension scheme as per that schedule.
- APPs can be structured to allow for conversion to buy-in or buy-out, including through a series of partial conversions over time. This flexibility, and the effective and transparent conversion mechanics, create a more certain de-risking journey.

Source: https://www.legalandgeneral.com/institutional/pension-risk-transfer/what-we-offer/app/
[135] AIB UK scheme completes £1.1bn de-risking deal, *IPE*, 13 February 2020. In May 2021, £61m of the AIB Group's APP was converted into a buy-in policy, which L&G said shows 'how APPs facilitate the de-risking journey'.

- In March, the Xylem UK Pension Plan completed a £255m bulk annuity transaction with Rothesay Life, covering around 2,500 final salary section members.[136]
- In March, L&G announced that it executed eight PRT deals worth £261m, ranging in size between £2.2m and £80m.[137]
- In March, the General Healthcare Group (GHG) Pension & Life Assurance Plan secured a £150m buy-in contract with Aviva to cover all 700 of its defined benefit members.
- In May, L&G completed a £650m buy-in with the *3i* Group Pension Plan.[138]
- Also in May, L&G completed a £70m buy-in for the ICI Pension Fund, the fund's 17th de-risking deal.[139]
- In June, the pension scheme of the Willis Group, now part of Willis Towers Watson, entered into a longevity swap with Munich Re. The swap covered £1bn pensioner liabilities of around 3,500 members. The longevity risk was transferred to the reinsurer via a Guernsey-based captive insurance company fully owned by the trustee of the scheme. It was established under Willis Towers Watson Guernsey ICC Limited, which is part of Willis Towers Watson's Longevity Direct solution allowing pension schemes to use a 'ready-made' incorporated cell company to access the reinsurance market.[140]
- In June, PIC executed a £280m longevity reinsurance deal with MetLife.[141]
- In July, the UBS (UK) Pension and Life Assurance Scheme executed a £1.4bn longevity swap with Zurich Assurance, covering around half the longevity risk in its £3bn DB scheme. Mercer, which acted as the adviser to the trustees, said the deal was structured as an 'innovative "pass through"' insurance contract, with 100% of the longevity risk reinsured by Canada Life Re.[142]
- In July, UBS executed a £1.4bn longevity swap with Zurich.[143]
- In July, the LV= Employee Pension Scheme converted a longevity swap held with ReAssure into a £800m buy-in with Phoenix Life. The buy-in covered the 4,100 pensioners and 200 deferred members who had been covered by the longevity swap, which had been agreed in 2012 and reinsured by Swiss Re. Swiss Re will continue to cover the longevity risk by providing reinsurance to Phoenix Life.[144]
- In July, the DB pension fund of Premaberg Holdings Limited, a UK manufacturer, completed a £5m bulk annuity transaction covering 50 members, of which around 80% are pensioners in payment. The buy-in was executed with Just Group and completed using Mercer's streamlined quotation service, which monitors buy-in

[136] Xylem UK Pension Plan secures £255m bulk annuity deal, *Pensions Age,* 2 March 2020.
[137] L&G completes £261m of pension risk transfer deals in March, *Pension Policy International*, 3 April 2020.
[138] L&G agrees £650m buy-in with 3i scheme, *Professional Pensions*, 27 May 2020.
[139] ICI fund teams up with Legal & General for 17th buy-in, *IPE*, 13 August 2020.
[140] Willis pension scheme strikes £1bn longevity hedge with Munich Re, *IPE*, 30 June 2020.
[141] https://www.artemis.bm/news/metlife-enters-uk-longevity-reinsurance-market-with-pic-transaction/
[142] UBS UK pension scheme enters into £1.4bn longevity hedge, *IPE*, 7 July 2020.
[143] *Aon's Risk Settlement Market Review 2020.*
[144] https://www.pensionsage.com/pa/LV-converts-longevity-swap-into-800m-Phoenix-Life-buy-in.php

pricing, demonstrating that 'smaller schemes can and do achieve successful bulk annuity transactions, despite continued high demand from much larger schemes'.[145]

- In July, the superannuation scheme for a farmers' cooperative secured the benefits of all its 120 members via a £13m buy-out with L&G.
- In July, the Countrywide Farmers Retirement Benefits Scheme agreed a £100m bulk annuity deal with L&G covering the benefits of 360 deferred members and 712 retirees. The scheme had entered the PPF assessment[146] in March 2018 following the insolvency of its sponsor, a rural retailer, livestock feed and energy supplier. However, it was overfunded on a PPF measure, and was therefore able to complete a so-called 'PPF+' transaction with L&G, which provided enhanced benefits compared with those available from the PPF, but less than those available from a full buy-out.[147]
- In August, the Littlewoods Pensions Scheme insured all its pension liabilities with a £930m buy-in covering deferred members with Rothesay Life, following a £880m buy-in covering pensioners with Scottish Widows in 2018.[148]
- Also in August, Hitachi UK agreed a £275m buy-in transaction for the remaining deferred and pensioner members of its DB pension scheme with L&G. Hitachi's first buy-in was with Scottish Widows in 2018.[149]
- In October, the Old British Steel Pension Scheme agreed a £2bn buy-in covering 30,000 members with PIC, with a buy-out expected at a later date.[150]
- In October, Rothesay executed a $320m longevity reinsurance deal with MetLife.[151]
- In November, the Marks & Spencer Pension Scheme completed a third set of buy-ins with Aviva (for £390m) and Phoenix (for £360m), with 80% of the scheme's £3.7bn pensioner liabilities now insured. Both of the new transactions were carried out under 'umbrella contracts' entered into in 2018.[152]
- In November, the Prudential (UK) Staff Pension Scheme agreed a £3.7bn longevity swap covering 20,000 pensioners. The deal involved a Guernsey-based captive insurance company owned by the scheme trustees, which provided access to the reinsurance market. Artex Risk Solutions established the captive entity, with Pacific Life Re as the reinsurer.[153]
- In November, the £2.9bn Pearl Group Staff Pension Scheme, one of Phoenix Group's pension schemes, completed a £731m buy-in with the group's life assurance company, Phoenix Life.

---

[145] £5m deal shows small schemes' ability to access bulk annuity market, *IPE*, 22 July 2020.
[146] That is, being considered for inclusion in the PPF due to sponsor insolvency.
[147] Pension scheme of collapsed rural retailer agrees £100m bulk annuity, *IPE*, 30 July 2020.
[148] Littlewoods scheme completes de-risking with £930m buy-in, *IPE*, 12 August 2020.
[149] Louron Pratt (2020) Hitachi UK completes £275 million pensions buy-in transaction, *Employee Benefits*, 26 August; https://employeebenefits.co.uk/hitachi-pensions-buy-in-transaction/
[150] Pension Insurance Corporation buys British Steel pension fund in £2bn deal, *Financial News,* 22 October 2020.
[151] https://www.artemis.bm/news/metlife-reinsures-320m-of-pension-longevity-risk-for-rothesay-life/
[152] M&S tops up de-risked pensioner liabilities with £750m set of buy-ins, *IPE*, 4 November 2020.
[153] Prudential Staff Pension Scheme agrees £3.7bn longevity swap, *IPE*, 11 November 2020.

- Also in November, the £1.4bn Baker Hughes UK pension plan completed a £100m buy-in with Just Group.
- Smiths Group completed a £290m buy-in with Aon as consultant in the August-December period.[154]
- In December, the Barclays Bank UK Retirement Fund completed a £5bn longevity swap transaction with RGA. Aon advised on all aspects of the transaction, including risk analytics, design and structuring, reinsurance selection and operational establishment. Tom Scott, principal consultant in Aon's risk settlement team, said: 'This transaction…demonstrates the capacity and appetite of the global reinsurance market to take on pension fund longevity risk, even in these challenging times'.[155]
- In December, the BBC Pension Scheme completed a longevity swap that covers more than £3bn of pensioner liabilities, Zurich Life was the insurer, while reinsurance was provided by Canada Life Re. The swap covers around one-third of the scheme's pensioner and dependant members.[156]
- In December, L&G executed a $2bn longevity reinsurance deal with MetLife.[157] It also completed a £400m APP with the L&G Group UK Senior Pension Scheme, covering 200 deferred members and 385 pensioner members.
- In December, the National Grid UK Pension Scheme completed an £800m buy-in with Rothesay.[158]
- In December, Maersk agreed £1.1bn buy-in with L&G.
- Also in December, the Aon Retirement Plan completed a £510m pensioner buy-in with Scottish Widows.[159]
- Finally, Willis Towers Watson completed a £3.3bn buy-in with an unnamed company, the market's largest bulk annuity to date.[160]

A number of other key developments took place in the UK in 2020.

In June, Prudential Retirement, a subsidiary of PICA, introduced 'asset-intensive' or 'funded reinsurance' to the UK PRT market, with a deal involving UK insurer Aviva. Funded reinsurance allows an insurer to transfer both the asset risk and longevity risk associated with pension and annuity liabilities.[161] It therefore protects the insurer not only

---

[154] *Aon's Risk Settlement Market Review 2020.*
[155] Barclays Bank UK scheme agrees £5bn longevity swap transaction, *IPE*, 14 December 2020.
[156] https://www.artemis.bm/news/bbc-pension-gets-3bn-longevity-swap-from-zurich-canada-life-re/
[157] https://www.artemis.bm/news/metlife-reinsured-2bn-of-longevity-risk-for-lg-in-2020/
[158] National Grid completes £800m buy-in with Rothesay, *Professional Pensions*, 9 December 2020.
[159] BBC scheme strikes £3bn longevity swap, Aon plan in £510m buy-in, *IPE*, 15 December 2020.
[160] Willis Towers Watson, *De-risking Report 2021: Keep calm and carry on de-risking*; https://www.willistowerswatson.com/en-GB/Insights/2021/01/keep-calm-and-carry-on-de-risking-de-risking-report-2021
[161] Asset-intensive reinsurance has been described as 'akin to a bulk annuity insurer doing its own buy-in behind the scenes. The insurer takes a portion of the buy-in/buy-out premium received from the pension scheme and passes it on to a reinsurer, often but not necessarily overseas. The reinsurer is then on the hook for providing monthly benefit payments to the insurer, and the insurer passes these payments on to the pension scheme or (following buy-out) the pensioners directly.' (Michael Abramson and Lara Desay (2023) The Insurance Regulator Takes a Look at Funded Reinsurance, *Life Risk News*, 2(8),10 August,

from the financial risk of an unexpected increase in life expectancy, but also from unexpected losses in the invested assets. In return for a single premium, the reinsurer pays monthly benefits to the insurer for as long as the insured members live.[162] Before this, Prudential Retirement only reinsured the longevity risk of other insurers. As a consequence of the huge growth in the UK PRT market, insurers have been looking for reinsurance partners to bring in additional capital and asset management expertise in order to help manage the asset and longevity risk they have assumed. Amy Kessler, then head of international reinsurance at PICA, said: 'Our entry into the funded reinsurance business is a natural place for us to expand. The presence of reinsurers like us, with both longevity capacity and asset management capabilities, will allow the UK market to continue to grow in new ways in the years to come. …At least five reinsurers… closed funded reinsurance transactions, resulting in meaningful volume and capacity to support the growth in the UK'.[163]

In June, PIC announced that it had invested £75m in debt issued by a UK housing association, Trident Housing Association. PIC said the maturity profile of the debt has been tailored to match PIC's pension liabilities in years where it is difficult to source low-risk, long-term, secure cashflows in the public bond markets. It will also meet Trident's borrowing needs to develop more social housing stock. The debt is secured on a pool of housing assets owned by the association.[164] In November, PIC invested £65m in Welsh housing association Pobl in order to create 10,000 new homes over the next 10 years, with the debt secured on social housing assets. PIC said: 'This investment complements our portfolio providing low risk, long-term, secure cashflows that match our pension liabilities for decades into the future'.[165]

In July, a report by L&G – *The Power of Pensions: How pension savings can help to build the UK's infrastructure and drive growth in all regions* – suggested that pension risk transfer providers, such as insurers, were willing to invest up to £190bn of pension assets in UK infrastructure over the next decade. According to the report, this would provide 20% of the investment needed to 'to support our society's needs', since investment in infrastructure was the 'key' to maintaining the long-term competitiveness of the UK economy and was 'vital' to delivering the government's 'industrial strategy' and would bring the economic stimulation and employment opportunities needed following the

---

https://liferisk.news/the-insurance-regulator-takes-a-look-at-funded-reinsurance/?utm_campaign=life-risk-news-volume-2-issue-8-august-2023). Greg Winterton adds: 'The asset-intensive life reinsurance (AILR) market in the US got its start in the aftermath of the Global Financial Crisis; the reduction in interest rates and regulatory changes made fixed deferred annuity books less palatable to hold on life insurance company balance sheets, with reinsurers offering a more fitting home for these liabilities' (Greg Winterton (2026) Will the US Asset Intensive Life Reinsurance Market Continue Recent Growth Spurt?', *Longevity & Mortality Investor*, 22 April, https://lminvestor.com/will-the-us-asset-intensive-life-reinsurance-market-continue-recent-growth-spurt).

[162] https://www.pacificlifere.com/content/dam/plre/GFS-deal-signing-press-release-Final.pdf

[163] Prudential Retirement enters funded reinsurance business, 30 October 2020; https://news.prudential.com/prudential-retirement-enters-funded-reinsurance-business.htm#.X5wS1QIIOSE.linkedin; Kessler (2021).

[164] UK housing association Trident secures £75m funding from PIC, *IPE*, 19 June 2020.

[165] PIC invest a further £65m in Welsh housing association Pobl, *IPE*, 26 November 2020.

Covid-19 pandemic. Long-term infrastructure investments are 'very attractive' to insurers because of their security and ability to generate steady cash flows for paying pensions as they fall due.[166]

However, pension funds face barriers to infrastructure investing. There is a shortage of supply of suitable assets and those that are available face stiff competition from commercial fund managers and sovereign wealth funds which have significant amounts of capital to deploy and are often prepared to accept lower returns. Also while bigger schemes can acquire assets directly, smaller schemes have to invest via infrastructure funds which involve higher fees. Morten Nilsson, chief executive of the British Telecom Pension Scheme, argues that the government could help stimulate supply through the UK Infrastructure Bank which was set up in June 2021 to support infrastructure that drives local economic growth or helps tackle climate change through loans, credit enhancement and equity investments. It has a £22bn budget, split between £12bn of equity and debt capital, and the ability to issue £10bn of government guarantees.[167]

The most significant pension event of 2020 was the introduction in June by TPR of an interim regulatory regime for the superfund pension consolidation market.[168] This is the market where pension schemes are consolidated into a larger fund, while remaining legally classified as pension schemes.[169] Consolidators must be able to demonstrate that they are well-governed, run by fit and proper people, and are backed by adequate capital, thereby reducing the chance that they later become insolvent and fall back on the PPF which bails out the pension schemes of insolvent sponsors.

Transferring to a consolidator might be a preferred option for a sponsoring company that wants to remove its pension liabilities, but cannot afford a full buy-out. The interim regime also explains how consolidators will be assessed and regulated. Capital adequacy is a key aspect of TPR's interim regime, since there will no longer be an employer covenant. TPR will require superfunds to hold sufficient assets to meet the promises to savers with a high degree of certainty. This will include the requirement for the scheme's liabilities (or technical provisions) to be calculated using specific assumptions set out in TPR's guidance and for additional assets to be held in a capital buffer. The interim regime sets a 1-in-100 risk of failure to pay benefits promised to scheme members in full, which is less stringent than the Solvency II regime for insurers which sets a 1-in-200 risk of failure. Superfunds must not extract any surplus from a scheme or its capital buffer until such time as either the pension liabilities are bought out with an insurer or final payments have been made. The interim regime will eventually be replaced by a legislative authorization and supervision framework.

---

[166] PRTs could help plug UK infrastructure 'mega-gap' – L&G, *Pension Policy International*, 9 July 2020.
[167] Val Cipriani (2021) Pension funds 'outcompeted' on UK green infrastructure investments, *Pensions Expert*, 29November 29; https://www.pensions-expert.com/Investment/Pension-funds-outcompeted-on-UK-green-infrastructure-investments
[168] https://www.thepensionsregulator.gov.uk/en/media-hub/press-releases/2020-press-releases/tpr-launches-tough-new-interim-regime-for-emerging-superfund-pension-market
[169] This contrasts with buy-outs where the liability for paying pensions is transferred to an insurance company.

Trustees need to be certain that a transfer to a superfund is in their members' interests. In October, TPR issued further guidance to trustees, setting out, three 'gateway principles' that transactions with superfunds must meet:

- A transfer to a superfund should only be considered if the scheme cannot afford to buy out now;
- A transfer to a superfund should only be considered if a scheme has no realistic prospect of buy-out in the foreseeable future, given potential employer cash contributions and the insolvency risk of the employer; and
- A transfer to the chosen superfund must improve the likelihood of members receiving full benefits.

TPR said: 'We expect ceding employers to apply for clearance in relation to a transfer from their scheme to a superfund, and for trustees to demonstrate they have done their due diligence in respect of the transfer'. Marc Hommel, senior pensions adviser at EY, said the guidance 'further signals that the government and pensions regulator are backing employers to access superfunds as more affordable solutions to discharge their pension obligations and, in distressed situations, for trustees to have better options for their members relative to the Pension Protection Fund. In the near term, superfund transactions are likely to take place only where the employer is distressed or insolvent'.[170]

The introduction of the interim regime renewed the debate between the consolidators and insurers about which model of PRT was safer. Insurers complain that because superfunds operate as pension funds, there is no legislation which sets standards on their capital requirements or investment strategy. Hetty Hughes, policy adviser at the Association of British Insurers (ABI), argued: 'By underwriting superfunds with the PPF, you are potentially privatizing the gains and socializing the losses'.

However, superfunds counter that they must also hold a capital buffer, and, unlike insurers, they cannot distribute profits to investors for three years. Antony Barker of the Pension Superfund even argues that superfund capital requirements are more onerous than those of the insurers: 'If you do the maths on their one-year test versus our five year test, they have to hold less capital than us. For the schemes in PPF assessment, insurers can cut members' benefits unilaterally in securing them, but superfunds cannot'.

Nevertheless, Hughes believes that the interim guidance is insufficient. Her concern is that superfunds are targeting well-funded schemes: 'That is where the risk of regulatory arbitrage becomes more acute. The regime doesn't need to be Solvency II compliant as it is trying to serve a market that can't afford a buy-out, but that doesn't mean the regime doesn't need to have similar features to Solvency II. For example, the life insurance industry has undergone stress tests recently, where they have to measure the impact if half their assets' credit rating were downgraded. This was found to be manageable, whereas TPR guidance simply says that superfunds can do their own homework and come up with their own stress tests. The regulator imposing a three-year ban on passing profits to

[170] UK regulator delivers superfund guidance for trustees, sponsors, *IPE*, 21 October 2020.

investors, is still insufficient. We might not see legislation for another five years and the guidance also says that the three-year rule is under review. What it doesn't say is that there are other ways of extracting value other than dividends. Performance fees and management fees are examples of the instructions private equity firms tend to put in place'. Andrew Bailey, the governor of the Bank of England, has also warned that the lack of firmer rules in TPR's interim guidance could pose a risk to financial stability.

It is certainly appears to be the case that superfunds have greater flexibility than insurers over investment strategy and can take on more investment risk. The Pension Superfund, for example, has a target allocation of 80% in a liability-driven investment (LDI) strategy,[171] with the rest in return-seeking assets. Barker accepts that, unlike insurers, superfunds have more freedom to adjust this target portfolio to the allocation that schemes already have in place: 'Our actual strategy will be driven to some extent by the schemes we inherit. One of our unique features is that we novate the schemes' existing portfolios. That ensures that our transaction costs are lower. So, if people already have private equity, we don't need them to sell it to provide us with cash and government bonds. The return-seeking assets are going to be drawn from public and private markets, but will probably allow us to focus more on private markets and illiquid assets because we expect that our peak cash-flows are going to be in the late 2030s to early 2040s so that gives us a lot of time to invest in illiquids. We can look at infrastructure, private equity, insurance-linked securities, land, property and other real assets'.

Chris Clark, DB policy lead at TPR, says: 'We don't see superfunds as a replacement for insurance, they are not targeting an insurance level of guarantee, but there are many schemes out there that can't afford that level of guarantee. For trustees considering a transfer, it is vital that they are doing so because it is in the best interest of scheme members'. Yet, David Weeks, co-chair of the Association for Member Nominated Trustees, points out that currently superfunds do not allow for member nominated trustees with any say in scheme governance.[172]

In October, a third superfund consolidator, Stoneport, joined the market. It was established by actuarial consultant Punter Southall with the aim of targeting the 4,350 DB schemes with fewer than 1,000 members. Punter Southall's own small DB scheme has joined up. Stoneport has the following aims: 'To address the growing number of problems facing trustees and sponsoring employers of small schemes, Stoneport [aims] to target running cost, investment management and end-game efficiencies, as well as improving governance standards'. Small schemes have running costs of £1,000 per member per year, compared with less than £100 for the largest schemes, leading to potential long-term savings of £40bn, comprising savings in lifetime running costs of £10bn, reduced investment management costs, the dividend from good governance, and the saving from joining

[171] Huw Jones and Sinead Cruise (2022) What is LDI? Liability-Driven Investment strategy explained, Reuters, 12 October 2022; https://www.reuters.com/markets/europe/what-is-ldi-liability-driven-investment-strategy-explained-2022-10-04/.
[172] Quoted in Mona Dohle (2020) Superfunds – New entrants to the DB consolidation market, *Portfolio Institutional*, 17 August.

together for an eventual buy-out.[173] In December 2021, Stoneport appointed Mobius Life as its investment platform provider. The platform will host Stoneport's investment funds which small schemes will be able to access without having to do their own market research.[174]

Another innovation in 2020 was the introduction of 'third-party capital solutions' (TPCSs).[175] These involve investors who provide a 'helping hand' to pensions schemes in the form of an additional capital buffer to schemes planning for a buy-out (or even just to achieve self-sufficiency) at a future target date if pre-agreed funding thresholds are not met. The link between the sponsor, the scheme and the trustees is maintained, so this model is different from the superfund model. It is also different from a buy-in which involves the bulk purchase of an annuity from an insurer. The model is most similar to the reinsurance sidecar discussed earlier, although with differences.

With a TPCS, the investors have a bigger influence on the investment strategy of the scheme. Indeed, the scheme trustees need to agree an investment strategy with the investors which will incorporate a return on the capital provided. The investment strategy can target higher returns and possibly enable lower sponsor contributions, since the capital buffer gives greater downside risk protection. However, once the investment strategy has been agreed, it cannot be changed without the consent of the investors, and the downside protection is limited to the size of the capital buffer. On the target date, if the scheme is sufficiently well funded to achieve a full buy-out, both the scheme and capital structure are wound up, with investors getting back their capital in full; otherwise the scheme reverts to normal operations and the investors receive a partial return of capital. TPCS investors are looking at schemes with a strong sponsor covenant, with liabilities below £250m, which are at least 85% funded on a buy-out basis, and with a significant proportion of total liabilites in the form of deferred pensions.

International developments outside the UK in 2020 included:

- In May, NN Life, executed a €13.5bn longevity reinsurance and swap transaction covering a portfolio of annuity policies for over 200,000 pensioners and dependants. The deal was reinsured with Canada Life Re, Munich Re and Swiss Re, and NN Group said it would lower its required capital and strengthen its capital position, with a 25 percentage points increase to its Solvency II ratio, which at the end of April 2020 stood at 220%. There will be an immediate upfront capital benefit, as well as lower future operating capital generation of approximately €90m p.a., although the ongoing longevity reinsurance premiums will reduce the

[173] New DB consolidator targets UK's small schemes, *IPE*, 20 October 2020.
[174] https://www.ipe.com/news/uk-db-consolidator-appoints-mobius-life/10056678.article
[175] Willis Towers Watson, *De-risking Report 2021: Keep calm and carry on de-risking*; https://www.willistowerswatson.com/en-GB/Insights/2021/01/keep-calm-and-carry-on-de-risking-de-risking-report-2021

International Financial Reporting Standards (IFRS) operating result before tax by approximately €30m p.a.[176]

- In June, actuarial consultant Milliman released the results of its new Milliman Pension Buy-out Index (MPBI) for the US. The MPBI uses the FTSE Above Median AA Curve, along with annuity purchase composite interest rates from a number of insurers, to estimate the average cost of a PRT annuity de-risking strategy. During May, the estimated cost to transfer retiree pension risk to an insurer dropped from 105.5% to 103.9% of a scheme's pension liabilities, as measured by its accumulated benefit obligation (ABO). The explanation for the fall is that discount rates in May dropped 27 basis points compared to a 10 basis point drop for annuity purchase rates, resulting in the relative cost of annuities decreasing by 1.6 percentage points.[177]
- The launch in August by Australian annuity provider Challenger – Australia's largest provider of annuities[178]– of a guaranteed floating rate lifetime annuity, with payments linked to the Reserve Bank of Australia (RBA) cash rate, so that annuitants would gain from any increase in interest rates.[179]
- In September, Mercer's US pension buy-out index indicated that the buy-out cost was only 97.7% of a US DB plan's accounting obligations, making buy-outs increasingly attractive. This followed a number of amendments to the US index which was originally launched in 2013 in response to changing to market conditions, including:
    - competition – the number of insurers who compete for annuity and buy-out transactions has doubled since 2012;
    - investments – insurer pricing is generally driven by the ability of insurers to source higher yielding, less liquid assets, such as private credit and commercial mortgages, which provide a good match for illiquid annuity buy-out liabilities; and
    - mortality – insurers have evolved their mortality underwriting techniques to better assess mortality risk at the individual participant level. This may often lead to lower pricing especially for transactions with smaller benefits and/or where benefit accruals have been frozen for many years.

  By contrast, the estimated long-term costs of maintaining pension liabilities on sponsor balance sheets was 105.2%, which reflects costs not included in accounting liabilities (i.e., ABOs), such as Pension Benefit Guaranty Corporation (PBGC)[180]

[176] https://www.artemis.bm/news/nn-life-transfers-eur-13-5bn-of-pension-longevity-risk-to-reinsurers/; *Aon's Risk Settlement Market Review 2020.*

[177] Milliman analysis: Estimated cost of retiree pension risk transfer drops significantly, from 105.5% to 103.9% in May, *Pension Policy International*, 24 June 2020.

[178] https://www.challenger.com.au/about-us/challenger-group

[179] Australia. Challenger launches floating rate annuity, *Pension Policy International*, 24 August; https://pensionpolicyinternational.com/challenger-launches-floating-rate-annuity/

[180] The PBGC is a mandatory US federally-chartered insurance plan that pays pensions to members of private defined benefit pension plans when the sponsor has become insolvent; https://www.pbgc.gov/

premiums, investment management and administration fees, and the risk associated with fixed-income defaults and downgrades.[181]

- In November, Milliman's US Pension Buy-out Index was modified to reflect the impact of competitive pricing on estimated buy-out cost and two new insurers were added to the index: Massachusetts Mutual Life Insurance Co. and Banner Life Insurance Company (Legal & General America). During September, the average estimated cost to transfer retiree pension risk to an insurer decreased by 60 basis points, from 102.9% of a plan's total liabilities to 102.3% of those liabilities, measured on a retiree ABO basis. Annuity purchase costs were even lower at 100.2% (down from 101.0% in August).[182]
- L& G completed its first two cross-country PRT transactions in 2020. The first, in May, covered IHS Markit's UK and US pension plans. The UK deal was for £37.8m and covered 150 members in the IHS (Global) Ltd. Pension and Life Assurance Scheme. The US deal was for $97.2m and covered 1,200 members in the IHS Retirement Income Plan.[183] In December, US chemicals company Evonik agreed a £544m full buy-in with L&G for its four UK pension schemes. This built on a $93m 'lift-out' completed by L&G for the US Evonik Corporation Retirement Plan in September. In a lift-out, a subset of pension scheme members are lifted out and transferred to an insurance company.[184] The main reason for a lift-out are to reduce administrative costs and, especially, the PBGC fixed-rate premiums of around $83 per participant.[185]

For many PRT providers, 2020 was a record year with L&G, for example, completing more than 60 deals worth over £8bn across its US and UK businesses.[186] Actuarial consultant Hymans Robertson has pointed out that since the PRT market took off in 2007, UK buy-ins/buy-outs (£180bn) and longevity swaps (£110bn) have insured £300bn of risk from DB pension schemes and expects an additional £700bn by the end of 2031, resulting in £1trn of DB pension scheme risk – around 50% of the total – being insured by then.[187]

---

[181] Revised Mercer U.S. Pension Buyout Index Methodology Shows That Costs of Annuity Buyouts Could Be Less Than Accounting Liability, *Pension Policy International,* 18 September 2020; https://pensionpolicyinternational.com/revised-mercer-u-s-pension-buyout-index-methodology-shows-that-costs-of-annuity-buyouts-could-be-less-than-accounting-liability/

[182] Milliman expands Pension Buyout Index to include competitive pricing rate, which drops to 100.2% in September, *Pension Policy International*, 4 November 2020; https://pensionpolicyinternational.com/milliman-expands-pension-buyout-index-to-include-competitive-pricing-rate-which-drops-to-100-2-in-september/

[183] https://www.ipe.com/news/uk-roundup-tpr-pipes-up-over-inter-dc-transfers-cross-country-prt-deal/10045567.article

[184] https://www.ipe.com/news/evonik-legal-and-general-add-544m-buy-in-to-us-de-risking-transaction/10050112.article

[185] https://www.pbgc.gov/prac/prem/premium-rates

[186] *Insurance Asset Management*, 3 February 2021.

[187] https://www.pensionpolicy.net/uk-roundup-1trn-of-db-pension-risk-to-be-insured-by-2031-says-hymans/

### *The Covid-19 pandemic*

The most significant global event of 2020 was, of course, the Covid-19 pandemic.[188] There was no longevity conference in 2020 as a result. Here we discuss the implications of the pandemic for pension schemes and the PRT market.

A study in May 2020 by Cairns et al (2020) of the UK predicted that if total Covid-19 deaths were capped at around 80,000, then this would have little overall effect on pension liabilities. By June 2022, total UK Covid-19 deaths were 200,000.[189] Liabilities fell since some pensioners would die, especially those in care homes, and that would be offset by a small increase in the average life expectancy of survivors. The UK government announced that it would save around £600m in state pension payments in 2020 as a result of an increase in excess deaths among the elderly. Given state spending on pensions of £100bn, this amounts to a reduction of 0.6%.[190] Given that pension scheme members are typically from higher socio-economic groups than the average, we should expect the liabilities of pension schemes to fall by less than this.

LCP's 2020 *Longevity Report* predicted that the value of a typical UK defined benefit scheme's net liabilities might fall by less than 0.25% as a direct result of the deaths of pensioners arising from Covid-19 in 2020. Since, total UK DB liabilities are around £2.2trn, excess deaths in 2020 due to Covid-19 could reduce liabilities by less than £5bn. However, this is dwarfed by the increase in liability values of over £50bn in 2020 as a result of falling stock markets and ultra low interest rates. The report concluded: 'The ultimate impact of deaths due to the coronavirus on the funding of DB pensions will be driven more by the economic and social consequences of the pandemic following 2020, in particular, a severe recession.' The report also found that longevity insurers and reinsurers are making very little – if any – allowance for Covid-19 in their longevity assumptions at the moment: 'Any impact on the affordability of longevity hedging has therefore been dwarfed by the impact of changes to the financial markets due to the pandemic'.[191] XPS Pensions estimated a larger fall in UK pension liabilities of between 1.5% and 3.5%, equivalent to £25bn-£60bn.[192]

Willis Towers Watson found that the UK bulk annuities and longevity swaps markets remained active all throughout the lockdown, implying that insurers' operating and financial models were robust enough to withstand the instability. Indeed, the widening of credit spreads created some exceptional pricing opportunities, which were taken

[188] XPS COVID-19 Tracker for UK: https://www.xpsgroup.com/what-we-do/technology-and-trackers/xps-covid-19-tracker/
[189] https://ourworldindata.org/explorers/coronavirus-data-explorer?facet=none&Metric=Confirmed+deaths&Interval=7-day+rolling+average&Relative+to+Population=true&Color+by+test+positivity=false&country=~GBR (29 June 2022).
[190] *Daily Telegraph*, 25 November 2020; https://www.statista.com/statistics/283917/uk-state-pension-costs/
[191] UK roundup: LCP on COVID-19's direct, indirect liabilities hit, *IPE*, 23 June 2020, https://www.ipe.com/news/uk-roundup-lcp-on-covid-19s-direct-indirect-liabilities-hit/10046384.article
[192] https://www.professionaladviser.com/news/4028930/covid-19-leaves-schemes-overestimating-pension-liabilities-research

advantage of by schemes already in the process of de-risking as well as schemes that had previously transacted and hence were in a position to execute a 'repeat deal' relatively quickly. WTW said it was involved in 20 buy-ins for 19 schemes, covering £8.6bn of liabilities, with most of these taking place during lockdown. It was also involved in five longevity swaps covering £14.7bn of liabilities. It noted: 'There is a significant appetite for reinsurers to take on new longevity swaps and this is producing very attractive pricing, and in several cases, schemes have been able to hedge at little or no cost, relative to their technical provisions'.[193]

WTW's *Emerging Trends in DB Pensions Survey 2020*[194] found that Covid-19 and the consequences for the wider economy are placing sponsors and schemes under strain, weakening the sponsor covenant: 1 in 3 say the sponsor's ability to support the scheme has weakened in the short term; 1 in 6 say it has in the long term. There is a trade-off between scheme security and business recovery: trustees aim to shorten the time to meet schemes' long term funding targets, while corporates expect to extend it. In the next 3 years, 4 in 10 schemes are looking to complete a bulk annuity transaction or longevity swap.

The economic impact of the Covid-19 pandemic following the lockdowns that most countries introduced to stop the virus spreading has affected the ability of workers and employers to contribute to private-sector pension schemes, according to the OECD's *Pensions Outlook 2020.*[195] It also points out that the liabilities of DB schemes are likely to grow. Although government wage support schemes meant that workers did not lose their entitlement to a state pension while they were furloughed, the huge cost of those schemes will inevitably impact the ability of governments to fund state pensions in the future.

Conducting an international comparison of mortality rates during 2020-21, Club Vita found that Canada's excess mortality rates versus the underlying trend were 6.3% and 2.9% in 2020 and 2021, while the US's were 14.3% and 14.4% and the UK's were 13.5% and 8.6%. Club Vita said 'Whether these levels of increased deaths continue and for how long will be vitally important for pension plans and insurers trying to understand future longevity trends in the UK, US and Canada'.[196] The World Health Organization Global Health Observatory estimated that global healthy life expectancy (HLE)[197] at age 60 fell by 1.1 years between

---

[193] Willis Towers Watson, *De-risking Report 2021: Keep calm and carry on de-risking*; https://www.willistowerswatson.com/en-GB/Insights/2021/01/keep-calm-and-carry-on-de-risking-de-risking-report-2021

[194] https://www.willistowerswatson.com/en-GB/Insights/2020/10/emerging-trends-in-db-pensions-survey-2020; October 26, 2020.

[195] Published 7 December 2020; https://www.oecd-ilibrary.org/finance-and-investment/oecd-pensions-outlook-2020_67ede41b-en

[196] https://www.clubvita.us/news-and-insights/top-charts-22-03-2021-excess-deaths

[197] The UK Office for National Statistics states that 'healthy life expectancy (HLE) is an extension of life expectancy (LE). We estimate the average amount of life a person can expect to live in "good" health by combining mortality data with general health status data. We define HLE as the average amount of time a person can expect to live in "very good" or "good" general health. It is a summary measure that reflects the average experience of a population, not the specific health trajectory of any individual'; https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/healthandlifeexpectancies/methodologies/healthylifeexpectancyqualityandmethodsguide

2019 and 2021 due to the Covid-19 pandemic; it fell by 1.4 years (from 16.61 to 15.21 years) over the same period in the Region of the Americas.[198]

In February 2024, the UK Office of National Statistics, on the basis of a new estimation methodology, revised down the number of excess deaths during the first pandemic year (2020), from 84,064 to 76,412. The highest number of excess deaths over the nine years prior to the pandemic was 30,858 in 2015, while the 2023 figure was 10,994. The new methodology allows for trends in mortality and the lags arising as a result of weekend deaths not being registered until the following week.[199] Richards (2024) proposed a method for removing the bias and distortion to the forecasts caused by the Covid-19 mortality shock; this also provided a robust starting point for making projections.

Evidence has begun to emerge about the long-term impact of the Covid-19 lockdowns that governments imposed. These affected people of all ages. Lockdown babies have been slower to reach milestones such as talking, pointing and waving goodbye, due to smaller social circles. The academic attainment of primary school pupils is significantly below pre-pandemic levels and their social and emotional development has been retarded. Lockdowns appear to have caused the premature ageing of teenagers' brains. The University of Washington found that the average acceleration in the development of the male adolescent brain was 1.4 years, while for females it was 4.2 years, possibly as a result of their heavier reliance on social relationships. A 2022 study by KCL found that disruption to education and prolonged social isolation 'exposed young people to many known risk factors for mental illness, raising serious concerns about their wellbeing'. The effect as endured: a 2023 study by University College London and the Sutton Trust found a third of 17 and 18-year-olds reported the legacy of Covid was still harming their education and mental health.

There has been an increase in UK university drop-outs that have been linked to school-leaving examinations during 2020-21 being graded on the basis of teacher assessments. The grades were sometimes higher than would have been awarded on the basis of exams and some students could not subsequently cope with university-level courses. The main reason given for dropping out was mental health, according to a 2023 study by KCL. Students who graduated missed out on the social interactions of university life, while those entering the job market while working from home were unable to learn from more experienced colleagues. In 2024, a UK study by the NHS Confederation and Boston Consulting Group found that thousands of new graduates were moving straight from university into long-term sickness, mainly with mental health conditions: 63,400 16-to-24 year olds in 2021-22, compared with 37,000 in 2019-20.

While young people's drug use decreased during Covid, alcohol use increased, mainly due to boredom. Research from NHS England and the University of Sheffield suggests that excess drinking could lead to thousands of extra deaths over the next 20 years. The research

[198] https://www.pensionpolicyinternational.com/impact-of-covid-19-on-healthy-life-expectancy-of-older-adults-in-the-region-of-the-americas/
[199] https://www.telegraph.co.uk/news/2024/02/20/excess-deaths-last-year-were-two-thirds-lower-than-expected/

also found that young adults aged 25 to 34 who were already heavier drinkers than their peers pre-pandemic were more likely to have increased alcohol consumption during and following lockdown. A similar pattern holds for the middle aged (in their late 30s, 40s and 50s) who were already drinking more than young adults before the pandemic. The acute anxiety, stress and boredom of lockdown, combined with the fact that many in this group were furloughed or laid off, led large numbers in this group to open a bottle of wine or can of beer much earlier in the evening than usual. As a consequence, the number of alcohol-related deaths recorded in the UK in 2022 at 10,046 was 4.2% and 32.8% higher than in 2021 and 2019, respectively. University of Essex research in 2022 showed that the switch to homeschooling resulted in mothers of school-age children experiencing stresses equivalent to getting divorce. Finally, research by the University of Exeter and KCL found that retirees in their late 60s and 70s experienced a decline in cognitive function during the pandemic, as a result of increased loneliness, depression and drinking and reduced exercise.[200]

**2021: Longevity 16**

The sixteenth conference (*L16*) was held in Helsingør near Copenhagen on 13-14 August 2021. It was hosted by PerCent at Copenhagen Business School and the Pensions Institute.[201]

In 2021, UK DB schemes completed £44.8bn worth of PRT transactions covering buy-ins, buy-outs, longevity swaps and assured payment policies. Excluding APPS (which do not hedge longevity risk), bulk annuity transactions were £27.7bn. Five longevity swaps were executed worth £17.1bn.[202] There were four bulk annuity deals of £1bn or more, compared with seven such jumbo deals in 2020, reflecting fewer multi-billion pound opportunities. However, buy-ins/outs between £100m and £1bn have trebled since 2015 and comprised one-third of all deals in 2021, while the number of deals below £100m fell by a third over the same period. The market was dominated by five insurers: Aviva (£6.2bn in deals, 22% market share), Standard Life (part of Phoenix Group, £5.5bn, 20%), L&G (£5.3bn, 19%), PIC (£4.7bn, 17%) and Rothesay Life (£3.0bn, 11%). Helped by rising yields on corporate bonds (a key investment vehicle in de-risking strategies), competition between insurers was intense and this was reflected in keen pricing.[203] UK consultancy Broadstone introduced SM&RT (Set Up, Monitor & Risk Transfer) Insure, a consolidation platform to help small to medium-sized schemes prepare for efficient PRT.[204]

---

[200] Rosa Silverman (2024) How Covid destroyed our lives, from newborns to pensioners, *Daily Telegraph*, 21 September; https://www.telegraph.co.uk//global-health/science-and-disease/how-covid-damaged-every-generation-from-babies-to-pensioner

[201] The conference proceedings for *L16* were published in September 2023 in the *Journal of Demographic Economics*, 89 (Special Issue 3: International Longevity Risk and Capital Markets Solutions): 299-312; https://doi.org/10.1017/dem.2023.2

[202] https://www.artemis.bm/longevity-swaps-and-longevity-risk-transfers/

[203] https://www.ipe.com/news/2021-uk-pension-risk-transfer-volumes-hit-439bn-with-record-core/10058708.article, https://www.pensions-expert.com/Investment/Derisking-activity-ramps-up-in-Q3

[204] https://lminvestor.com/2025-provides-activity-change-and-evolution-for-uk-pension-risk-transfer-market/

In March 2020, the UK Institute and Faculty of Actuaries' Continuous Mortality Investigation (CMI) released the CMI_2020 Mortality Projections Model.[205] This is used by most DB schemes in the UK and it requires schemes to choose what allowance to make for the pandemic. By 2021, there was enough information for schemes to form a best estimate. For most schemes, an appropriate pandemic allowance was a reduction of 1.5% to 3.5% in liabilities. For a scheme that is 90% funded, this could mean a 25% reduction in the deficit.[206]

The Longevity Index for England (LIFE Index) was introduced in 2021 (together with a LIFE App). It was developed by Andrew Cairns of Herriot Watt University and uses data science methods (e.g., the random forest algorithm which helps identify non-linearities in the data) and machine learning to analyze life expectancy at the neighbourhood level, based on ONS data, such as the Index of Multiple Deprivation. The LIFE Index indentifies distinct socio-economic and urban-rural differences in mortality levels. Income and employment deprivation are responsible for 80-90% of the variation in life expectancies, while urban-rural differences account for 10%.[207]

Highlights for 2021 in the UK included:

- In February, L&G agreed a £570m pensioner buy-in deal with Deutsche Bank's UK pension scheme; it was the £4.5bn scheme's first de-risking strategy.[208]
- In March, the AXA (UK) Pension Scheme executed a £3bn longevity swap with Hannover Re, covering a significant number of deferred members who comprise around 95% of the 16,000 members. This was helpful for the scheme's investment strategy as it provided increased cashflow certainty.[209] This transaction helped to open up the longevity market for pension schemes to reinsure non-pensioners.
- Also in March, an unnamed UK pension scheme executed a £6bn longevity swap with PICA and Zurich Assurance acting as an intermediary on a pass-through basis. The pass-through deal was the first used by PICA with a UK-based insurer, having previously used Guernsey- and Bermuda-based captive solutions. Rohit Mathur, the new head of international reinsurance at PICA, said 'We see the use of a third-party onshore UK-regulated insurer as a limited recourse intermediary as the logical next step in the de-risking solutions we can offer for clients in our evolving business model'.[210]
- In April, PIC made a £37.5m debt investment in Welsh housing association Wales and West Housing which will fund the building of 2,500 new homes over the next

[205] https://www.actuaries.org.uk/learn-and-develop/continuous-mortality-investigation/cmi-investigations/mortality-projections
[206] Updating life expectancy assumptions for the new CMI_2020 model, *XPS Express for Employers*, March 2021.
[207] https://liferisk.news/using-local-knowledge-to-fine-tune-life-expectancy-analysis/
[208] https://www.pensionpolicy.net/deutsche-bank-inks-buy-in-deal-for-u-k-pension-fund-with-lg/
[209] https://www.ipe.com/news/axa-uk-scheme-signs-3bn-longevity-swap-for-mostly-deferred-liabilities/10051692.article
[210] https://www.professionalpensions.com/news/4030529/pica-reinsures-gbp6bn-longevity-risk-unnamed-scheme

five years. PIC said: 'Sourcing long-dated, secure cash flows is important to PIC. The investment backs our long-term pension liabilities, while having the beneficial outcome of putting PIC's capital to use in parts of the economy where funds are vitally needed'.[211]

- In May, the AIB Group UK Pension Scheme agreed a £61m transaction with L&G to convert a tranche of its existing APP into a buy-in policy. Covering both deferred members and new retirees, the transaction is the first example of a APP being partially converted into a new buy-in policy. The conversion builds on the original £250m APP transaction with the AIB Group scheme, and follows a £400m APP transaction with the L&G Group UK Senior Pension Scheme.
- In May, the Wyeth Group Pension and Life Assurance Scheme, a Pfizer Group subsidiary, completed a £190m bulk purchase annuity buy-in, covering 2,000 members.[212]
- Also in May, the ICL Group Pension Plan (whose sponsor is Fujitsu) completed a £3.7bn longevity swap with Swiss Re.[213]
- In June, the Tui Group UK Pension Trust agreed two buy-ins for £794m with L&G.[214]
- In June, PIC announced it was investing £200m in the development and operation of 10 new retirement living communities comprising around 2,000 older residents, via a partnership with Octopus Real Estate. PIC's aim is again to generate index-linked cash flows.[215] In the same month, it invested £175m in the senior secured debt funding of 18 Spanish solar parks owned by Q-Energy which in turn receives payments from the Spanish electricity system and so can guarantee an agreed level of return and predictable cashflows for PIC.[216]
- In July, L&G completed its third APP, another deal (valued at £925m) with its own DB pension scheme, covering 2,000 retired and 2,800 deferred members.[217]
- In July, the Pearl Group Staff Pension Scheme completed a second £998m buy-in with Phoenix Life.[218]
- In July, the Kingfisher Pension Scheme completed a £900m bulk purchase annuity transaction with Aviva, covering 8,000 of the £3.7bn scheme's members.[219]

---

[211] https://realassets.ipe.com/news/pension-insurance-corporation-lends-to-welsh-housing-association/10052418.article
[212] https://www.ipe.com/news/251m-in-de-risking-deals-as-aib-converts-app-wyeth-seals-buy-in/10053116.article
[213] https://www.ipe.com/news/icl-group-scheme-strikes-37bn-longevity-hedge/10052771.article
[214] https://www.ipe.com/news/uk-roundup-tui-trust-strikes-800m-buy-in-pair-lothian-names-new-ceo/10053151.article
[215] https://realassets.ipe.com/news/pic-to-invest-up-to-200m-in-uk-retirement-communities-via-octopus-jv/10060819.article
[216] https://realassets.ipe.com/news/pic-increases-investment-in-renewable-energy/10053393.article
[217] https://www.ipe.com/news/legal-and-general-completes-925m-assured-payment-policy-transaction/10054195.article
[218] https://www.pensions-expert.com/DB-Derisking/Pearl-Group-pension-fund-completes-further-buy-in
[219] https://www.ipe.com/news/kingfisher-pension-scheme-inks-900m-bulk-annuity-with-aviva/10054147.article

- In September, Aviva completed a £320m bulk purchase annuity transaction with the John Laing Pension Fund, covering 1,850 pensioners.[220]
- In September, Just Group introduced medical underwriting for its equity release mortgage range, by taking account of the client's medical conditions and lifestyle factors in determining the borrowing rate and limit.[221]
- In September, Standard Life entered the equity release market with a range of lifetime mortgage products launched in partnership with Key Group, under the brand Standard Life Home Finance. Earlier in the month, Phoenix Group bought a portfolio of equity release mortgages worth £300m from Just Retirement. In 2020, the equity release market totalled £3.89bn, while £1.17bn of property wealth was unlocked by over-55 homeowners in the second quarter of this year, according to the Equity Release Council.[222]
- In October, the Metal Box Pension Scheme agreed a £2.2bn buy-in, covering 10,300 pensioners and 2,200 non-pensioner members, with PIC as a step towards a full buy-out in November.[223]
- In October, the Sanofi Pension Scheme has signed a £760m buy-in policy with L&G, covering 2,900 retirees.[224]
- In December, the Imperial Tobacco Pension Fund completed a £1.8bn bulk purchase annuity transaction, covering 6,600 pensioner members, with Standard Life.[225]
- In December, the Gallaher Pension Scheme completed a £1.7bn bulk purchase annuity (BPA),[226] covering 7,600 members, with Standard Life. Standard Life said the assets underlying the deal will be used to continue its investment into UK infrastructure and socially responsible projects that are vital to the UK's post-pandemic recovery.[227]
- In December, an unnamed pension scheme executed a £2.6bn longevity swap with Zurich and Metlife. It was MetLife's first pension scheme longevity swap transaction.[228]
- In December, the Phoenix Group completed a £1.8bn longevity swap covering its UK pension liabilities with Metlife.

[220] https://www.pensionpolicyinternational.com/aviva-announces-320m-bulk-annuity-deal-with-the-john-laing-pension-fund/
[221] https://www.professionaladviser.com/news/4037321/group-launches-medical-underwriting-equity-release
[222] https://www.professionaladviser.com/news/4037061/standard-life-launches-lifetime-mortgage-range-key-group
[223] https://www.ipe.com/news/metal-box-scheme-in-wind-up-mode-after-striking-22bn-buyout/10055419.article
[224] https://www.ipe.com/news/sanofi-uk-pension-scheme-agrees-760m-buy-in-with-landg/10055597.article
[225] https://www.ipe.com/news/uk-roundup-tobacco-scheme-strikes-18bn-buy-in-deal/10057343.article
[226] Alternative name for a buy-in.
[227] https://www.ipe.com/news/de-risking-roundup-gallaher-pensions-17bn-buy-in-deal-with-standard-life/10057512.article
[228] https://www.ipe.com/news/metlife-zurich-complete-35bn-longevity-swap/10057535.article

- In December, the pension scheme of biochemical and food company CSM Limited completed a £86m buy-in with Just Group. The scheme received pricing from multiple insurers in three weeks using the PwC Insure service.[229]
- In December, Just Group also completed £345m buy-in transaction with the UK pension scheme of an unnamed global distribution company. The deal covered 1,000 deferred members and 900 pensioner members.[230]
- Also in December, the benefits in the pension plan of metal flow engineering company Vesuvius were fully insured with PIC following a seventh buy-in. The first buy-in with PIC was in 2012. With the latest deal, valued at £305m, over £600m of liabilities were insured with PIC.[231]

International developments outside the UK in 2021 included:

- Athora Netherlands executed two longevity swaps: the first was valued at €4.7bn with Canada Life Re in March and the second was valued at €3.3bn with RGA in September.
- Aegon executed a €7bn longevity swap with RGA in December. It had now reinsured 40% of the longevity risk of its Dutch pension insurance book. The deal improved the solvency ratio of Aegon's life business by 15 percentage points, releasing capital for new business growth.[232]
- NN Life executed a €4bn longevity swap with RGA also in December.[233]
- These transactions all involved Dutch insurers, but the larger Dutch pension plans have also been considering buy-outs as funding ratios have improved as a result of strong equity markets and higher interest rates. With funding ratios above 120%, accrued pension benefits can be transferred to an insurer with guaranteed indexation. In 2021, 44 plans out of a total of 129 reached this threshold (e.g., ING and ABN AMRO Bank) compared with 15 in 2020. Competition from insurers has also increased, with NN Group, previously the only provider, joined by Aegon, Zwitserleven and Lifetri. It is however possible, under new Dutch legislation, for accrued DB benefits to be transferred to a DC plan and the Dutch regulator expected up to 70% of plans to do this.[234]
- In December, the Amsterdam School of Economics and Nationale-Nederlanden opened the Research Centre for Longevity Risk.[235] The research centre 'will study developments in survival rates and life expectancy and how these developments are affected by a variety of factors. This includes studying demographic trends and medical developments, as well as the impact of local socioeconomic conditions and the quality of our living environment. The research findings pertaining to expected

[229] https://www.ipe.com/news/csm-limited-scheme-completes-86m-deferred-heavy-buy-in/10058660.article
[230] https://www.ipe.com/news/metlife-zurich-complete-35bn-longevity-swap/10057535.article
[231] https://www.ipe.com/news/vesuvius-seals-seventh-final-buy-in-with-pic/10057145.article
[232] https://www.ipe.com/news/aegon-reinsures-dutch-longevity-risk/10057149.article
[233] https://www.artemis.bm/longevity-swaps-and-longevity-risk-transfers/
[234] https://www.ipe.com/news/higher-funding-ratios-and-dc-transition-fuel-dutch-demand-for-buyouts/10056974.article
[235] https://rclr.nl

developments in life expectancy will also provide a foundation for studying the financial and social impact of these trends'.

- US corporate pension plan buy-out sales totaled $38bn in 2021, beating the previous record of $36bn set in 2012.[236] There were a number of large PRTs. For example, in August, Lockheed Martin Corp purchased group annuity contracts from Athene Holding to transfer $4.9bn pension plan liabilities, covering 18,000 retirees and beneficiaries.[237] In September, HP Inc agreed to purchase a group annuity contract from PICA to transfer $5.2bn in liabilities, covering 41,000 retirees and beneficiaries in the HP Pension Plan.[238]
- In November, State Street Global Advisors launched a deferred lifetime income annuity within the University of California's retirement plan. The deferred annuities are linked to target-date asset-allocation funds, which invest a portion of the plan member's assets in annuity contracts as the member approaches retirement age.[239]
- Canada introduced longevity funds which are mutual funds with mortality credits as a middle ground between pension funds and annuities. Purpose Investments launched the Longevity Pension Fund in 2021, while Guardian Capital launched GuardPath Longevity Solutions in 2022.[240]

**2022: Longevity 17**

The seventeenth conference (*L17*) was held online on 12-13 September 2022. It was hosted by the Pensions Institute.[241]

The effects of long Covid began to be observed in the UK in 2022. According to a study by the Institute for Fiscal Studies, there were 2m people with long Covid who have taken some time out of work, with 110,000 unable to work at any one time. Sufferers typically report long Covid for up to six months after they are first infected. Given that total unemployment and total vacancies both equal 1.3m, this implies 110,000 people had a 'meaningful effect' on the jobs market and the wider economy. The Office for National Statistics estimated that 8.75m people of working age were 'economically inactive', implying they were not in work or looking for work. This has risen by around 400,000 since the pandemic began. Of these, 2.3m were long-term sick (absent for more than four

[236] https://www.pensionpolicyinternational.com/us-pension-risk-transfer-market-posts-record-breaking-2021/
[237] https://www.pionline.com/pension-risk-transfer/lockheed-martin-offloads-another-43-billion-pension-liabilities-insurer
[238] https://www.pensionpolicyinternational.com/hp-ships-off-5-2-billion-in-pension-liabilities/
[239] https://www.pensionpolicyinternational.com/us-new-lifetime-annuities-in-401k-plans-could-cut-advisors-out-of-the-picture/
[240] https://www.pensionpolicyinternational.com/canada-are-longevity-fund-solutions-going-to-change-the-retirement-income-game/
[241] The conference proceedings for *L17* were published in April 2024 in *The Geneva Papers on Risk and Insurance - Issues and Practice*, 49(2): 229–233, Special Issue on Longevity Risks; https://doi.org/10.1057/s41288-024-00314-3; Supplementary materials, https://static-content.springer.com/esm/art%3A10.1057%2Fs41288-024-00314-3/MediaObjects/41288_2024_314_MOESM1_ESM.pdf

weeks), up by more than 200,000 since February 2020. Not only was this damaging for the economy, it also badly affected the finances of long Covid sufferers who experienced a reduction of income of around £1,100 per month on average.[242]

Douglas Anderson, Founder of Club Vita, reported that UK mortality rates for 2022 were below pre-Covid-19 levels. As social distancing measures were gradually relaxed at the start of 2022, Covid-19 cases increased, but the strain was less dangerous than at the beginning of the pandemic: 'Statistics show that there are many people in hospital *with Covid*, but *not because of Covid*. What we are seeing is the Covid has completed its journey …to now being a largely manageable endemic. When Covid first struck, the disease was materially more dangerous (a death rate of something like 10x flu). With vaccinations,[243] changes to the way we live our lives, better treatments and the emergence of less deadly dominant variants, the risk of death has thankfully reduced. …The patterns in North America are following a similar trajectory to the UK. But the picture in China is very different with Shanghai in lockdown [in May 2022]. It's a good reminder that despite the improvement, we have not reached "herd immunity", and some experts argue that we probably never will'.

Looking to the long-term and the implications for projecting pension liabilities, Anderson identified four trends for the UK:

1. Waiting times for health treatments have lengthened: Since 2018 the number of people in England on a waiting list has risen from 4m to 6m, and the average wait time has almost doubled from 7 weeks to 13 weeks.[244]

2. More public money going into the UK National Health Service (NHS): To deal with this waiting list, in 2022, the government introduced a health and social care levy which will raise £12bn a year. Given that the NHS budget is around £150bn, 'that's useful money at the margin, but could be quickly used up by the continued aging of the population'.

3. Labour shortages are encouraging employers to prioritize employee wellbeing: 'Covid continues to cause a big shake out in working practices. Trade unions highlight the loss of 200,000 older workers, reversing a previously healthy trend in employment levels in older people. Further, workers show little appetite to

[242] https://www.telegraph.co.uk/business/2022/07/27/long-covid-shrinks-workforce-110000/

[243] The World Health Organization estimated that Covid-19 vaccinations saved more than 1.4 million lives across Europe between December 2020, when the vaccine rollouts began, and March 2023; https://www.medrxiv.org/content/10.1101/2024.01.12.24301206v1. Further, undervaccination (receiving fewer than the recommended number of SARS-CoV-2 vaccine doses) could be associated with increased risk of severe COVID-19 outcomes (i.e., COVID-19 hospitalisation or death) compared with full vaccination (receiving the recommended number of SARS-CoV-2 vaccine doses), according to a meta-analysis of UK data published in *The Lancet*; https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(23)02467-4/fulltext

[244] In the UK at the height of the pandemic in 2020, most cancer deaths occurred at home as hospitals prioritized Covid patients; https://www.telegraph.co.uk/news/2021/05/07/majority-cancer-deaths-occurred-home-last-year-hospitals-prioritised

return to a daily commute to the office, after showing that the job can be done perfectly well from home: "hybrid working" – part office-based, part home-based looks like it will be the "new normal" for those whose jobs are suitable. Employers are increasingly appreciating that they will need to invest more in health and wellbeing to attract and retain older employees. This emphasis on prevention in middle aged workers is very welcome. By focussing on slowing down aging by improving lifestyle, it is possible to soften the demands of the aging population on future treatment in the NHS system'.

4. More private money going into genetic research: 'Covid showcased the first mass benefit of the genetics research industry (mRNA[245] vaccines), leading to sharp share price gains for the visionary investors. This stunning success is encouraging other investors to back the biotechnology sector. The increase in research capacity bodes well for the volume of future advances. Take a look at the Deep Knowledge Group to see the growing coalition of researchers and investors'.

Anderson concludes: 'My personal sample of emerging themes offers three positive, but slow, improvements from three different stakeholder groups: government, employers and investors. Collectively, these may turn out to be more significant for pensioner longevity – when the inevitable peaks and troughs from year to year are smoothed out – than today's spike in waiting lists for treatments'.[246]

In 2022, for the first time, all eight insurers in the UK market were in a position to offer full-scheme buy-outs with member-facing administration services, 'a reaction to the increasing maturity of final salary schemes and a growing conviction over targeting buy-out'.[247]

The funding position of UK defined benefit schemes increased by 20% during 2022 to 104% of liabilities (with assets of £1,456bn and liabilities of £1,394bn). This was largely explained by gilt yields rising by 3 percentage points and a corresponding 35% reduction in the value of liabilities, moving many UK schemes into a surplus position for the first time for many years.[248]

WTW reported that 2022 was the biggest on record for pension scheme de-risking in the UK, with £60bn of bulk annuity and longevity swap transactions completed, comprising £40bn in buy-ins and buy-outs and £20bn in longevity swaps. A key reason was higher gilt yields and widening corporate bond spreads which increased pension scheme funding

[245] Messenger RNA (mRNA) is a type of single-stranded RNA involved in protein synthesis; https://www.genome.gov/genetics-glossary/messenger-rna
[246] Douglas Anderson (2022) UK deaths now below pre COVID levels: what's the long-term COVID legacy for pensioner longevity?, Club Vita, 11 May; https://www.clubvita.co.uk/news-and-insights/uk-deaths-now-below-pre-covid-levels-whats-the-long-term-covid-legacy-for-pensioner-longevity
[247] https://www.ipe.com/news/2021-uk-pension-risk-transfer-volumes-hit-439bn-with-record-core/10058708.article
[248] https://www.professionaladviser.com/news/4062207/defined-benefit-pensions-gbp400bn-funding-improvement-2022

levels and lowered buy-out prices significantly. Around 30% of pension schemes anticipate de-risking their liabilities in the next three years.[249]

There was increasing automation of the pricing process which removed manual input and made use of interpretable machine learning, ensuring greater accuracy. This has improved workflows by making them more consistent, cost effective and reliable, which, in turn, has increased pricing agility and speed to market.

Despite this, some insurers were struggling to keep up with the current levels of demand, according to a report by Aon, especially the teams responsible for pricing transactions. This has made it harder for smaller schemes to attract the attention of insurance companies. Although transactions under £100m have increased in recent years due to insurer innovation, small schemes were now 'having to compete harder for insurer engagement and potentially show flexibility over their auction timing and form'.[250]

Legal & General Investment Management's (LGIM's) DB Health Tracker found that a typical DB scheme could meet 98.8% of accrued pension benefits as of 30 June 2022: 'The increase in both nominal and real interest rates benefited a typical scheme due to underhedged liabilities. This was largely offset by poor performance of growth assets relative to expectations. Overall, however, our Expected Proportion of Benefits Met (EPBM) measure managed to …reach a new high'.[251] A PwC survey of UK DB pension plans in July 2022 found that 80% expected to reach their long-term funding target (of ensuring pensions are paid in full) within the next nine years: 85% of both the smallest plans with assets of less than £300m and the largest plans with assets above £5bn said they could achieve this, whereas only 75% of medium-size plans felt they could. Asset returns were a key component of the strategy, with 92% of plans saying that they would rely in whole or in part on assets returns and 41% relying solely on asset returns; 8% had hedged their investment risk and were relying on sponsor contributions to reach their long-term funding target. PwC said that pension funding levels had improved dramatically over the last couple of years, with many schemes moving into a surplus position.[252] This will clearly increase the demand for buy-outs in the UK over the next decade.

In order to ensure they could meet their targets for buying out, pension funds were also increasing the inflation sensitivity of their portfolio in response to the increase in inflation following governments' pandemic quantitative easing programs and the increase in commodity prices following the Russian invasion of Ukraine on 24 February 2022. A poll

[249] Willis Towers Watson (2023) Shifting up a Gear – De-risking Report 2023; https://www.ipe.com/news/bulk-annuity-longevity-hedging-deals-set-to-reach-60bn-says-wtw/10064524.article

[250] https://www.ipe.com/news/insurers-stretched-as-uk-pension-de-risking-demand-rises/10061581.article

[251] https://www.ipe.com/news/uk-roundup-db-schemes-health-reaches-new-high/10061802.article? By 31 August 2022, the average UK pension fund was 100.2% funded on a long-term target basis for the first time since aggregated records began, according to XPS Pensions Group's DB: UK funding tracker; https://www.ipe.com/news/uk-roundup-pension-funds-achieve-100-funding-on-long-term-targets/10061950.article?

[252] https://www.ipe.com/news/uk-db-schemes-expected-to-reach-long-term-funding-target/10061323.article

of global pension funds by investment consultancy bfinance indicated that the funds were planning to increase their exposure to infrastructure (48%), private debt (39%) and real estate (36%). Alternatives were more popular as an inflation hedge than equities (18%), inflation-linked bonds (12%) and commodities (8%).[253]

In the light of the UK's departure from the EU, the UK government announced revisions to Solvency II on 17 November 2022. According to Pelkiewicz et al. (2019), the reason for this was as follows: 'Following the implementation of Solvency II, the risk margin[254] came under considerable criticism for being too large and too sensitive to interest rate movements. These criticisms are particularly valid for annuity business in the United Kingdom. …A further criticism is that mitigation of the impact of the risk margin has led to an increase of reinsurance of longevity risks, particularly to overseas reinsurers'.

The new regime for UK insurers is known as 'Solvency UK' and involves:

- a reduction in the 'risk margin', including a cut of 65% for long-term life insurers;[255]
- more sensitive treatment of credit risk in the 'matching adjustment',[256] such as allowing insurers to invest in assets with 'highly predictable' (rather than strictly 'fixed') cashflows and assets with prepayment risk, such as callable bonds (up to 10% of the total matching adjustment);
- a significant increase in flexibility allowing insurers to invest in long-term assets such as infrastructure and other assets with a construction phase;
- a meaningful reduction in the current reporting and administrative burden on firms; and
- a new regime for start-up insurers, with adjusted entry requirements such as a lower capital floor, lower expectations for key personnel and governance structures, and

[253] https://www.ipe.com/news/pension-funds-turn-to-alternatives-for-inflation-protection/10059146.article

[254] The risk margin represents the potential costs of transferring insurance obligations to a third party should an insurer fail. It is the difference between the technical provisions (the transfer value) and the Best Estimate Liabilities (BELs). It is calculated in Solvency II using the 'cost-of-capital method' as an insurer's baseline solvency capital requirement (SCR) for unhedgeable risks multiplied by the cost of capital at 6% and discounted at current interest rates. Unhedgeable risks are risks that cannot be hedged or easily transferred to a third party, due to the absence of a deep and liquid market. A current example is longevity risk. The risk margin does not include credit and market risks as compensation for uncertainty arising from those risks is considered to be already adequately reflected in the BELs;
https://www.risk.net/definition/risk-margin

[255] 30% for non-life insurers.

[256] The matching adjustment give insurers capital relief for holding specific long-term assets which match the cash flows of a designated portfolio of life or annuity insurance and reinsurance obligations. It permits insurers to discount their liability cash flows at a higher rate than the risk-free rate, resulting in a lower liability value and hence lower regulatory capital. The higher rate is intended to reflect the illiquidity premium in the return on the long-term assets held and is calculated as the difference between the spread on these assets above the risk-free rate and the 'fundamental spread' or credit risk premium (i.e., the expected cost of default and downgrade of these assets); https://www.bankofengland.co.uk/-/media/boe/files/prudential-regulation/publication/2022/solvency-ii-review-matching-adjustment-and-reforms-to-the-fundamental-spread

exemptions from some reporting requirements, which is also aimed at developing the UK insurtech sector.[257]

The combined effect of these reforms is expected to release 10-15% of the capital currently held by life insurers.[258] They have been welcomed by UK insurers and are likely to lead to greater insurer capacity for schemes looking to de-risk through buy-ins and buy-outs. John Baines, partner at Aon and head of its bulk purchase annuity team, said the reforms struck a good balance between capital relief and policyholder protection, with the PRA likely to be reassured that the level of capital requirement would still be a 'gold standard approach to ensuring insurers had a high chance of meeting pension benefit obligations.[259] Chris Anderson, head of BPA consulting at EY, said: 'Risk margin rules at the moment drive insurers to transact a huge amount of longevity reinsurance when they complete a PRT deal. Two potential consequences of the proposed changes are that first, it may encourage insurance companies to carry out slightly less reinsurance, which could be beneficial on price for pension schemes, and secondly the risk margin on what remains will be lower, which also should be beneficial on price'. A key problem which slows down the pace of transactions is a shortage of qualified staff. According to Anderson: 'Everyone is trying to find people. Insurance companies need people to run the quotation process and to onboard schemes. Employee benefit consultants also need additional staff – everyone is resource constrained'.[260]

A report from PIC entitled *Investment Unleashed*[261] argued that appropriate reform to Solvency II could unlock 'tens of billions of pounds' to invest in infrastructure and social assets in the UK, including renewable energy and social housing. PIC estimated its planned investment of £30bn in productive finance by 2030 could increase to £50bn. According to the report, the ideal reform of Solvency II would:

- preserve insurer balance sheet resilience throughout the cycle – protecting policyholder pensions – whilst discouraging investment in relatively riskier assets in overvalued markets;
- encourage investment into productive finance throughout the cycle;
- ensure a competitive UK insurance industry – especially when compared to insurers operating under the EU Solvency II regime.[262]

However, Michael Luo, associate director at fiduciary manager Cardano, pointed out that in 2022 life insurers were facing geopolitical risks and a macroeconomic climate that had

[257] https://www.skadden.com/insights/publications/2022/11/from-solvency-ii-to-solvency-uk
[258] https://ukfinancialservicesinsights.deloitte.com/post/102hnw5/the-uk-governments-consultation-on-solvency-ii-part-1-risk-margin-and-matchin
[259] https://www.ipe.com/news/analysis-uk-solvency-ii-reforms-and-the-pensions-buyout-market/10058506.article
[260] Quoted in Greg Winterton (2022) Solvency II Reform Proposals Could Drive Increased Pension Risk Transfer Activity, *Life Risk News*, Volume 1, Issue 8, December; https://liferisk.news/solvency-ii-reform-proposals-could-drive-increased-pension-risk-transfer-activity/
[261] https://www.pensioncorporation.com/media/200562/investment-unleashed-2021-211223v1.pdf
[262] https://www.ipe.com/news/solvency-ii-reform-could-free-up-tens-of-billions-of-pounds-for-uk-infra-says-pic/10057177.article

not been experienced in over 40 years, with the prospect that they could see the quality of their investments deteriorate through increased credit downgrades and defaults. In addition, any insurers looking to raise hybrid debt capital in the near-future may experience higher borrowing costs than in recent years, whilst any increase in volatility in interest rates and credit markets could create pressure on liquidity management. This implies that trustees and sponsors will need to put more focus on understanding insurers' financial strength, risk management and capital resilience when undergoing an insurer-led risk transfer exercise, to ensure the most appropriate insurer is selected to deliver benefits to their scheme members.[263]

In response to this, some pension plan trustees had become concerned about post-transaction protection. According to Alan Pickering, President of BESTrustees: 'If the trustees do not realize until the eleventh hour that once the scheme has no money, they will be depending on insurance or internal indemnities to guarantee that they will sleep at night for the rest of their lives, because ambulance chasing lawyers will not come after them claiming the benefit payments are wrong. You do not want to double bank external insurance and internal indemnities, but it is important to send trustees into retirement with peace of mind'.[264]

One of the most significant events of the year was the impact on UK pension funds' liability-driven investment (LDI) strategies – used by 73% of DB schemes according to Mercer[265] – following UK government's 'mini-Budget' of 23 September. The financial markets responded unfavourably to the unfunded tax cuts announced, predicting that the UK's national debt would increase substantially. The prices of gilts fell sharply and pension funds faced huge increases in collateral requirements as their hedging contracts for protecting against lower interest rates (principally in the form of interest rate swaps and gilt repurchase agreements[266]) moved out of the money. Pension funds were forced to sell gilts in an illiquid market to meet cash margin calls and this reduced gilt prices even further. The Bank of England was forced to step in and stabilize the market by agreeing to purchase gilts directly from pension funds. Although pension funds faced a severe liquidity crisis at the time, their solvency position actually improved, since the rise in gilt yields helped to reduce the value of their liabilities.[267]

This experience is expected to provide a further boost to buy-outs and buy-ins. It was also expected to be disappointing news for pension scheme consolidator companies that rely on LDI strategies to hedge their risks.[268] A survey by Russell Investments found that the

[263] https://www.pensionsage.com/pa/Trustees-urged-to-consider-insurers-financial-strength-as-PRT-market-approaches-unique-juncture.php
[264] Quoted in Mark Dunne (2022, Editor) Endgame investing - pi roundtable, July; https://www.portfolio-institutional.co.uk/roundtables/endgame-investing/
[265] *Portfolio Institutional*, October 2022 (p.44).
[266] See, e.g., *An Introduction to Liability Driven Investment*, Insight Investment, November 2021.
[267] Sarah Breeden (2022) Risks from leverage: how did a small corner of the pensions industry threaten financial stability? Bank of England, 7 November; https://www.bankofengland.co.uk/-/media/boe/files/speech/2022/november/sarah-breeden-speech-at-isda-aima.pdf.
[268] https://www.pensionpolicyinternational.com/uk-ldi-fallout-will-spur-pension-funds-to-seek-life-sector-arrangements/

volatility following the UK government's 'mini-Budget' had influenced asset allocation decisions, with moves away from developed markets (32% of respondents) and emerging markets equities (12%), as well as property (17%) exposure. Instead, investment grade credit (25%) and high yield credit (13%) were the key beneficiaries of this trend, as was infrastructure (16%) and private credit (12%), 'reflecting the perceived attractiveness of the risk/return opportunities available in these asset classes'.[269]

Another issue was currency movements. Sterling fell significantly against the US dollar during 2022 from $1.35 to $1.21. This reduced the costs for both US sponsors of UK pension plans and US insurers offering PRT solutions to UK plans.

A total of £44.7bn in buy-outs, buy-ins and longevity swaps were executed in 2022, of which £28.7bn were buy-ins and £15.7bn were in five longevity swaps.[270] The largest providers were Legal & General, Standard Life, Aviva, PIC and Rothesay, with Just Group having a record year with £2.6bn in transactions. Around 30% of buy-in and buy-out transactions were run on an exclusive basis in 2022 and did not go through an auction process.[271]

Highlights for 2022 in the UK included:

- In February, the Lloyds Banking Group Pensions Scheme executed a second longevity swap, covering £5.5bn of liabilities. It was structured as an insurance contract with Scottish Widows as the insurer and SCOR as the reinsurer, taking over the longevity risk.[272]
- In February, L&G agreed a £370m buy-in with London Heathrow's BAA Pension Scheme, securing the benefits of more than 1,400 retirees.[273]
- In February, L&G announced it would invest £2.5bn of DB pension assets in UK build-to-rent (BTR) projects over the next five years, creating more than 7,000 new homes.[274] This was followed up in April with an announcement that it would invest a further £2bn in affordable UK homes over the next five years, creating 10,000 new homes.[275] In August, it invested £500m in 'later living' residential homes in a joint venture with the NatWest Bank pension fund.[276]

---

[269] https://www.ipe.com/news/uk-mini-budget-accelerates-db-schemes-de-risking-says-russell-investments/10063686.article

[270] https://www.ipe.com/news/bulk-annuity-volumes-reach-278bn-according-to-aon/10065718.article?; https://www.artemis.bm/longevity-swaps-and-longevity-risk-transfers/

[271] Estimates from Hymans Robertson; *Insurance Asset Management*, 6 October 2023.

[272] https://www.professionalpensions.com/news/4044972/lloyds-scheme-completes-gbp-5bn-longevity-swap

[273] https://group.legalandgeneral.com/en/newsroom/press-releases/legal-general-agrees-c-370m-buy-in-with-heathrow-s-baa-pension-scheme

[274] https://realassets.ipe.com/news/landg-to-inject-25bn-of-pension-money-into-uk-build-to-rent-projects/10058092.article

[275] https://realassets.ipe.com/news/landg-to-invest-2bn-of-pension-money-into-affordable-uk-homes/10059125.article

[276] https://realassets.ipe.com/news/landg-and-natwest-pension-fund-to-invest-500m-in-uk-later-living-villages/10054341.article

- In March, the Air Canada (UK) Pension Trust Fund completed a £380m buy-in deal with PIC, covering 1,400 members.[277]
- In March, the Royal Mencap Society completed a £61m bulk annuity transaction for its pension scheme, covering 710 members. Following a one-round appointment process, the scheme was able to benefit from Canada Life and Aon's streamlined internal legal process. These efficiencies secured competitive pricing for the scheme.[278]
- In March, the Newell Rubbermaid UK Pension Scheme has agreed to a £225m buy-in with L&G, covering 800 retirees and 900 deferred members.[279]
- In May, the £10.3bn British Steel Pension Scheme II agreed a second buy-in with L&G, insuring around 25% of its liabilities. The first buy-in was completed at the end of 2021 and covered 5% of the liabilities.[280] In December, the scheme completed a further £2bn buy-in with L&G. This covered 30% of its liabilities, and brought the total liabilities insured to 60%.[281]
- In May, PIC made a £130m debt investment in UK social housing provider Raven Housing Trust to help fund the development of 630 homes by 2026.[282] In September, PIC invested £105m to forward fund a new 'net-zero in-operation office' in Manchester to be let to the Government Property Agency for 25 years. In October, it invested £55m in Northern Ireland-based Clanmil Housing Association which will be used to build 1,400 new homes by 2026[283] and provided £102m of debt financing to Corelink Rail Infrastructure, a UK rolling-stock lessor.[284] Also in October, it invested £40m in the secured debt of UK social housing provider, Mhs, to fund the development of 600 new properties.[285] In November, it financed the construction of a £200m residential skyscraper in the West Midlands region of England.[286] Also in November, it created Senior Living Investment Partners with Octopus Real Estate which made its first £115m investment in a retirement community in St Albans.[287] In December, it invested £40m of debt in Housing Solutions, a housing association which owns and manages around 7,500 properties

[277] https://www.ipe.com/news/uk-pension-schemes-sign-buy-in-deals-with-pic-just-group/10058758.article
[278] https://www.ipe.com/news/uk-roundup-charity-completes-61m-bulk-annuity-transaction/10058643.article
[279] https://www.ipe.com/news/uk-roundup-rubbermaid-scheme-completes-buy-in-with-legal-and-general/10058607.article
[280] https://www.pensionsage.com/pa/BSPS-II-secures-two-buy-ins-with-L-G.php
[281] https://www.ipe.com/news/british-steel-pension-scheme-completes-2bn-buy-in-with-legal-and-general/10064456.article
[282] https://realassets.ipe.com/news/uk-social-housing-provider-raven-secures-130m-funding-from-pic/10059795.article
[283] https://realassets.ipe.com/news/pic-invests-55m-in-clanmil-housing-association/10062602.article
[284] https://realassets.ipe.com/news/uk-rolling-stock-lessor-corelink-gets-102m-pic-loan/10062627.article
[285][285] https://realassets.ipe.com/news/pic-invests-in-secured-debt-issued-by-uk-housing-association-mhs/10062935.article
[286] https://realassets.ipe.com/news/pic-funds-200m-residential-skyscraper-project-in-birmingham/10063144.article
[287] https://realassets.ipe.com/news/pic-and-octopus-real-estates-uk-retirement-living-venture-makes-first-investment/10063332

in the south-east of England.[288] In each case, the aim was to secure long-dated index-linked cashflows for the purpose of paying the 'pensions of our current and future policyholders over coming decades'.[289]

- In June, the House of Fraser's Beatties & Jenners Pension Scheme insured £600m of liabilities via a buy-out with PIC, covering 3,850 deferred members and 5,050 pensioners.[290]
- In June, the Phoenix Group provided £90m of long-term funding to regulated social housing provider, Alliance Homes, with the aim of generating index-linked cash flows.
- In July, the UBS (UK) Pension and Life Assurance Scheme extended its July 2020 longevity hedge by £500m to include 50% of its deferred members, those over 60. The combined hedge covered two-thirds of its DB liabilities. The deal involved Zurich Assurance as the insurer and Canada Life Re acting as the reinsurer.[291]
- In July, the Whitbread Group executed a £680m bulk purchase annuity covering approximately 8,000 members of its pension fund with Standard Life. Standard Life said: 'we receive a one-off premium from the scheme and then guarantee that member benefits will be paid into the future. This premium is invested across a broad range of assets to ensure we are able to meet the future liabilities. Given that member benefits will be paid out over decades we can afford to take a long-term view in the way we invest and make allocations to illiquid investments. We aim to invest 60% of our illiquid assets in sustainable investments including in areas like renewable energy, infrastructure, affordable housing and healthcare and education, …supporting some of society's most vulnerable people as well as …projects with a positive environmental impact, such as the provision of renewable electricity'.[292]
- In August, the Equity Release Council reported that 47,000 new and returning customers withdrew £3.13bn from their properties during the first half of 2022, an increase of 37% on the same period in 2021. The majority (54%) of the withdrawals were in the form of lump sum lifetime mortgages rather than drawdown lifetime mortgages. The Council believes that this is 'influenced by customers' continuing desire to gift money to younger family members and share their property wealth across generations'. Stephen Lowe, group communications director at Just Group, said the 'demand for equity release has recovered strongly from the pandemic wobbles. …Homeowners may be using equity release to generate lump sums, extra income or for estate-planning'.[293]
- In August, Phoenix Group announced it would acquire Sun Life Assurance Company of Canada (UK), a closed book UK life insurance company, from Sun Life Financial for £248m. The deal was expected to deliver £470m of incremental

[288] https://realassets.ipe.com/news/pic-provides-40m-of-debt-for-uk-social-housing-provider/10063997.article
[289] https://realassets.ipe.com/news/pic-invests-105m-to-forward-fund-gpa-hub-office-project/10062435.article
[290] https://www.ipe.com/news/uk-roundup-house-of-fraser-plan-strikes-600m-buyout/10060379.article
[291] https://www.ipe.com/news/ubs-uk-scheme-extends-longevity-hedge-by-500m/10060899.article
[292] https://www.ipe.com/whitbread-group-pension-fund-completes-680m-buy-in-with-standard-life/10061094.article
[293] https://www.professionaladviser.com/news/4054181/equity-release-activity-26?

long-term cash generation, inclusive of cost and capital synergies. The insurer had about 480,000 in-force policies and £10bn of assets under administration, of which £2.5bn were annuities that would remain reinsured with Sun Life Financial.[294]

- In August, Standard Life completed a £1bn buy-in of the WH Smith Pension Trust, covering around 13,000 members. As with other insurers, the assets underlying the contract will be used to continue Standard Life's program of investing into UK infrastructure and socially responsible projects, such as renewable energy, infrastructure, and affordable homes.[295]
- In August, L&G agreed a £50m full scheme buy-in with the Boots Supplementary Pension Plan, covering the benefits of more than 110 members. Lisa Varley, a senior consultant in Aon's risk settlement group, which advised the trustees, said: 'The successful outcome illustrates that there are excellent opportunities for sub-£100m schemes, as long as insurers can see a clear line of sight to a successful transaction'.[296]
- In August, Railpen, the UK railways pension scheme, purchased a life-science business park in Oxford for £29m with plans to attract leading companies in scientific research as tenants and generate 'enhanced returns' for scheme members.[297] In October, Railpen agreed to fund the redevelopment of a mental health facility in Northern England in exchange for a 30-year lease on the site which will deliver inflation-linked returns for the scheme.[298]
- In September, the Barloworld UK Pension Scheme completed a £484m full scheme buy-in with Just Group, insuring the benefits of around 3,000 pensioners and 1,800 deferred members.[299]
- In September, the Yell Pension Plan executed a full scheme buy-in with PIC, covering the remaining £370m of liabilities, having completed a £200m buy-in also with PIC in 2014. All 1,800 plan members became PIC policyholders.[300]
- In October, the Cobham Pension Plan has concluded a £530m buy-in with Standard Life, covering around 3,000 members.[301]
- In November, the Balfour Beatty Pension Fund completed a £1.7bn longevity reinsurance transaction (i.e., swap) covering 15,000 members with Zurich UK as the insurer and SCOR taking on 100% of the longevity risk using a 'pass-through' structure.[302]

---

[294] https://www.professionaladviser.com/news/4054283/phoenix-group-acquire-sun-life-uk-gbp248m
[295] https://www.ipe.com/news/standard-life-completes-1bn-buy-in-of-the-wh-smith-pension-trust/10061476.article
[296] https://www.ipe.com/news/boots-supplementary-agrees-50m-pension-buy-in-with-landg/10061569.article
[297] https://realassets.ipe.com/news/railpen-buys-29m-life-science-business-park-from-aew/10061697.article
[298] https://realassets.ipe.com/news/railpen-to-fund-monkwearmouth-hospital-redevelopment/10062796.article
[299] https://www.ipe.com/news/barloworld-uk-scheme-completes-484m-buy-in-deal-with-just-group/10061961.article?
[300] https://www.ipe.com/news/uk-roundup-yell-pension-plan-completes-370m-buy-in-deal-with-pic/10062218.article?
[301] https://www.ipe.com/news/uk-roundup-cobham-scheme-completes-530m-buy-in/10062986.article
[302] https://www.ipe.com/news/uk-roundup-balfour-beatty-in-17bn-longevity-transaction/10063743.article

- In November, an unnamed UK pension scheme sponsored by a Fortune 500 company completed a £1bn longevity swap with Zurich as insurer and PartnerRe as reinsurer. The deal covered both pensioner and non-pensioner members.[303]
- In November, the TT Group scheme executed a £400m buy-in deal with L&G, covering 5,000 members.[304]
- In December, the Barclays Bank UK Retirement Fund executed a £7bn reinsurance transaction, with reinsurance provided by PICA.[305]
- In December, the Amey pension fund executed a £400m buy-in deal with PIC, covering 3,473 members, including 1,938 deferred members.[306]
- In December, The Interserve Pension Scheme completed a £400m buy-in with Aviva, covering around 7,000 members.[307]
- In December, the Tioxide Pension Fund agreed a £430m buy-in with L&G, securing the benefits of around 2,700 retirees and deferred members.[308]
- In December, the Co-operative Pension Scheme's £2.1bn Bank Section completed a full £1.2bn buy-in with Rothesay Life, covering all the liabilities of 2,474 pensioners and dependants and a further 6,531 deferred members.[309]
- Also in December, Rothesay Life executed a £762m buy-in for the Morrisons Retirement Saver Plan, covering 2,650 pensioners and dependants and 5,500 deferred members.[310]

There were a number of significant international developments outside the UK in 2022.

The US PRT market had its most successful year to date, with 568 transactions valued at $51.8bn, of which $48.3bn was accounted for by 562 single premium buy-outs, while the remainder were buy-ins.[311] This was largely due to improved funding ratios rising from 87.9% in 2020 to 95.8% in 2021 and to 100.7% in 2022, on the back of strong equity market performance and higher interest rates. With rising levels of inflation, a potential recession, and geopolitical uncertainty, plan sponsors wanted to protect themselves from market downturns. Some of the PRTs were lift-outs, with plans transferring some of their

[303] https://www.professionalpensions.com/news/4060514/fortune-500-sponsored-scheme-completes-gbp1bn-longevity-swap
[304] https://www.ipe.com/news/partnerre-in-1bn-longevity-swap-deal-with-uk-fortune-500-scheme/10063540.article
[305] https://www.professionalpensions.com/news/4061710/barclays-uk-retirement-fund-seals-gbp7bn-longevity-deal
[306] https://www.ipe.com/news/british-steel-pension-scheme-completes-2bn-buy-in-with-legal-and-general/10064456.article
[307] https://www.pensionsage.com/pa/Interserve-Pension-Scheme-completes-400m-buy-in-with-Aviva.php
[308] https://www.ipe.com/news/uk-roundup-tioxide-pension-fund-in-430m-buy-in-deal-with-landg/10064566.article
[309] https://www.pensions-expert.com/DB-Derisking/Co-operative-Pension-Scheme-completes-1.2bn-full-section-buy-in
[310] https://www.pensionsage.com/pa/Morrisons-agrees-762-m-buy-in-with-Rothesay.php
[311] https://www.pensionpolicyinternational.com/us-pension-risk-transfer-market-keeps-setting-records/; https://www.pensionpolicyinternational.com/u-s-pension-plan-buyouts-reach-record-volume-in-2022/; https://www.pensionpolicyinternational.com/us-pension-risk-transfers-spiked-in-2022-due-to-higher-interest-rates-report-shows/

pension risk to an insurance company, but most followed plan terminations – and a consequential increase in annuity purchases – by plans that were over 100% funded. The market was also very competitive with 21 active insurers, including newcomers Global Atlantic, RGA and American National, compared with 10 in 2012.[312] As a result of this competition, the Milliman Pension Buyout Index was 98.9% of plans' retiree ABO, while the average annuity purchase cost across all insurers was 103.7%. This meant that the competitive bidding process was estimated to save plan sponsors on average around 4.8% of PRT costs (as of February 28). By September 30, the cost savings had fallen to 3.0% of PRT costs due to 'insurers having less appetite for interest rate risk, or less assets available for transactions'.[313] The average premium per transaction was $90m in 2022, up from $55m in 2018.[314] Another development is the entry of reinsurers into the market, providing additional balance sheet capacity to insurers, but without being direct writers in the market. There is beginning to be some interest in buy-ins in the US market, but longevity-only transactions, such as longevity swaps, are still rare, because they will not reduce PBGC premiums.[315] A prediction for 2023 will be artificial intelligence enhanced modelling of mortality and longevity risks which could lead to more longevity risk-transfer deals.[316]

One of the largest disclosed US transactions of the year was completed in June by Lockheed Martin Corp. which purchased group annuity contracts for 13,600 retirees from Athene Holding valued at $4.3bn.[317] An even bigger one was completed in September, when PICA and MetLife each agreed to reinsure 50% of the pension benefit payments of 100,000 IBM (International Business Machines) plan members. The total value of the PRT transaction was $16bn, making it the second-largest deal in the US market.[318] In December, Western & Southern Financial Group executed a $1.7bn longevity swap with RGA.[319]

In the Netherlands, there has been a movement away from longevity derivatives towards longevity swaps (or longevity reinsurance). According to Andre de Vries, vice president business development at RGA, longevity derivatives, which dominated the Dutch market between 2012 and 2017, 'are based on the mortality risk of the general Dutch population, as opposed to a specified portfolio of insured beneficiaries. In addition, these longevity derivatives are structured to transfer more remote (out-of-the-money) longevity risk over a limited term and the benefit (claim) under these longevity derivatives is capped at a pre-

[312] https://www.institutionalinvestor.com/article/b1xzjngjkysg4t/Companies-Race-to-Offload-Pension-Risk-as-Market-Volatility-Rises
[313] https://www.pensionpolicyinternational.com/milliman-analysis-competitive-pension-risk-transfer-buyout-rate-rises-320-basis-points-to-100-1-during-september/
[314] https://www.pensionpolicyinternational.com/global-pension-risk-transfer-monitor-record-h1-transaction-volumes-in-uk-and-us/
[315] https://liferisk.news/still-plenty-of-capacity-for-growth-in-robust-us-prt-market/
[316] https://www.ipe.com/north-america/us-sponsors-back-pension-buyouts/10064707.article?
[317] https://www.pensionpolicyinternational.com/us-milliman-analysis-competitive-pension-risk-transfer-buyout-rate-hits-all-time-low-in-february-at-98-9/; https://www.pionline.com/pension-risk-transfer/us-corporate-pension-plan-buyouts-hit-record-123-billion-q2-limra-survey
[318] https://www.pensionpolicyinternational.com/prudential-and-metlife-entrusted-to-fulfill-16b-in-pension-obligations-for-100000-ibm-retirement-plan-participants-and-beneficiaries/
[319] https://www.artemis.bm/longevity-swaps-and-longevity-risk-transfers/

defined amount. Compared to longevity reinsurance, longevity derivatives require only a limited set of data to be shared with the risk takers and impose less due diligence requirements on the ceding company compared to a reinsurance transaction. On the other hand, it is more challenging to determine the reduction in Solvency Capital Requirement under Solvency II (SII) resulting from these derivatives because there is no perfect fit between the longevity risk transferred and the longevity risk of the insurance company'.

In 2018, the Dutch market switched to longevity reinsurance because if the introduction of SII in the EU in January 2016: 'As longevity swaps transfer all the longevity risk of a specified portfolio of pension obligations over their full remaining term (which can easily be more than a few decades), these transactions are more expensive than longevity derivatives. On the other hand, because these reinsurance transactions exactly match the underlying liabilities of the insurance companies, these instruments allow insurance companies to fully release the SCR for the corresponding longevity risk. …SII has an explicit SCR for longevity risk which resulted in clear capital relief from longevity risk transfer transactions. This was not the case under the prior regulatory regime'.

Dutch longevity swaps have introduced a number of new features:

- Recouponing (or rebalancing) longevity swaps. The objective of recouponing is to provide additional protection to the party that is facing a positive value of the longevity swap at a future moment during the term of the transaction. Under this mechanism, the fixed leg (the premiums) of the longevity swap is adjusted in case its present value has become materially different (either higher or lower) compared to the prevailing present value of the floating leg (the claims).
- Accommodating a bail-in. This is one of the resolution tools included in the 2019 Recovery and Resolution Act for insurers which might allow pension obligations to be reduced so that an insurer can continue in business.
- Extending longevity reinsurance with asset performance risk or 'asset-intensive' (AI) life reinsurance.[320] This is a longevity swap whereby the present value of the fixed leg is paid at inception. To mitigate the counterparty credit exposure of the insurer on the reinsurer resulting from this initial settlement, a collateral arrangement forms part of AI reinsurance. Under this collateral arrangement, the reinsurer is responsible for maintaining a portfolio of assets within pre-agreed investment guidelines and restrictions. As asset performance risk is very capital intensive, Dutch insurers that are actively managing their capital position, are considering to also reinsure (some of the) asset performance risk resulting from these pension buy-outs. Such an approach might give them the opportunity to also offer very large pension buy-outs that they might otherwise not be comfortable executing because of the substantial capital implications.[321]

[320] In asset-intensive life reinsurance, the reinsurer takes on both the liabilities (which carry longevity risk) and the assets of the corporate pension plan.

[321] Andre de Vries (2022) Update on Longevity Risk Transfer in the Netherlands, *de actuaris*, December, 18-20; https://www.ag-ai.nl/view/51882-DA-30-2-art-deVries.pdf

In July, AXA Germany announced the transfer of a portfolio of around 900,000 conventional life and annuity insurance contracts worth €19bn in assets under administration to Athora Germany for a purchase price of €610m. It will take five years to transfer the contracts, beginning in 2023.[322]

The Australian Prudential Regulation Authority (APRA) introduced a retirement income covenant in July 2022.[323] Regulated superannuation funds (or other registrable superannuation entities (RSEs)) are required to formulate a retirement income strategy (the strategy) for their members' decumulation phase which will improve their retirement outcomes and be in their best financial interests. Although not stated explicitly, the aim is to encourage greater use of lifetime annuities where that is appropriate for members. The A$220bn Australian Retirement Trust (ART) – formed from the merger of QSuper and Sunsuper in February 2022[324] – has introduced a lifetime pension product which is like an annuity. It offers a market-based income for life in a set-and-forget product in which the super funds are pooled with other investment funds to cover fees and costs and only a proportion of the assets are used to provide the pension. Other providers include *Challenger* Life and Generation Life which in May 2022 introduced an investment-linked lifetime annuity.[325] Previously, most retirees switched to an account-based pension which keeps their pension pot invested in the same pool of assets as in accumulation. Income from the account is tax free, but there is a minimum drawdown of 5% every year which increases as members get older.[326]

In March, the first longevity deal in Asia was completed, when Swiss Re agreed with Singapore-based composite insurer, NTUC Income, to co-insure the longevity risk on the latter's annuity book, by sharing any future payments to annuitants who live beyond their life expectancy. This enabled NTUC Income to improve its own capital efficiency and strengthen its solvency position.[327]

In May, the Bermuda Monetary Authority proposed amending the Insurance Act 1978 to introduce a new innovative class for long-term insurers (Class IILT). The BMA said it believed that market developments in the next decade will lead to a conflux of insurance, capital markets, artificial intelligence, and distributed ledger technology: 'The Class IILT is intended for, but not limited to, innovative business models, such as those insurers that utilize digital assets for their operations… [which] would enhance liquidity and risk transfer efficiency'.[328]

---

[322] https://www.ipe.com/news/axa-germany-transfers-19bn-insurance-portfolio-to-athora/10061129.article
[323] https://www.apra.gov.au/implementation-of-retirement-income-covenant
[324] https://www.top1000funds.com/2022/03/super-and-sunsuper-merge-to-form-new-institutional-giant/. ART is the second largest super fund after the A$260bn AustralianSuper.
[325] https://frsltd.com/latest-news/generation-life-launches-australias-first-investment-linked-lifetime-annuity-solution-on-investpro-from-frs/
[326] https://www.ipe.com/asia-pacific/letter-from-australia-superfunds-focus-on-retirement-income/10057677.article
[327] https://www.swissre.com/media/press-release/nr-20220308-swiss-re-partners-with-ntuc-income-longevity-arrangement-shield-against-future-variation-incomes-annuity-book.html
[328] https://www.reinsurancene.ws/bma-introduces-new-innovative-class-for-long-term-insurers-class-iilt/

One of the most significant events of 2022 was the opening of the Longitude Exchange – as the first digital marketplace for trading longevity risk in index-based format – in Bermuda which is regulated by the Bermuda Monetary Authority (BMA), Bermuda's financial regulator.[329] It describes itself as the Longevity Risk Marketplace for connecting hedgers and investors on a platform optimized for trading longevity risk. Its mission is to build an efficient and deep market for trading longevity risk, helping ensure the stability of individuals retirement income and the global financial system by: helping pension funds and insurers manage liabilities at a lower cost; providing investors better access to an uncorrelated asset class; enhancing the efficiency of trading longevity risk; and improving the security of the financial system.

The Longitude Exchange platform handles documentation, trade set-up, primary issuance, valuations, and secondary trading. Its tools streamline the process of hedging and investing in longevity risk. For hedgers, there are tools for: hedge construction – construct trades optimized for risk and capital objectives; hedge analysis – measure hedges' impact on risk and capital positions; hedge placement – conduct auctions, negotiate terms and execute deals; hedge reporting – receive reporting, payment and collateral instructions; and hedge management – increase or decrease hedges through secondary trading. For investors, there are tools for: longevity modeling – models and datasets to generate longevity scenarios; investment analysis – price transactions using longevity scenarios; investment execution – place bids and negotiate terms with counterparties; on-going valuations – live quotes and historical trades to mark positions; and secondary trading – list positions, request bids, and buy listed transactions.[330]

In May, the Longitude Exchange linked up with Dedomainia to advance the techniques and processes for monitoring, administering, and valuing index-based longevity risk hedges. In December 2016, Dedomainia had launched a web-based platform designed for longevity swap calculations called LISA (Longevity Insurance Servicing and Administration).[331] In September, the Longitude Exchange announced it had raised seed funding from the Deep Knowledge Group, a consortium of commercial and non-profit organizations active in several technological domains including Longevity, AI, FinTech, and InvestTech.

Dr Erik Pickett, Chief Content Officer at Club Vita, argues that the key to developing a successful life market is the:

> *commoditization of longevity risk, i.e., the development of fungible, tradable financial instruments linked to longevity risk that increase the efficiency of each step of the risk transfer chain and ultimately the creation of a deep liquid market for longevity risk. Commoditization should attract more, much needed, capacity in longevity risk takers. This is expected largely to come from capital markets investors entering the market, attracted by returns diversified against key financial*

[329] https://www.longitude.exchange/
[330] https://www.bayes.city.ac.uk/data/assets/pdf_file/0012/701013/MICHAELSON-Avery.pdf
[331] https://www.artemis.bm/news/efficient-management-of-longevity-transactions-key-for-counterparts/

*risks, with some extra capacity also released from existing players due to standardization and automation.*

*It is often not economical for small pension funds to enter into complicated indemnity contracts to remove longevity risk. Streamlining of contracts such as those implemented by Mercer and Zurich have opened up this market to smaller players to a certain extent, but complete commoditization would open it up further. By simplifying the process and increasing the supply of risk takers, commoditization should create competitive pricing for longevity risk transfers. The clearing price will of course be affected by any increase in demand, but price loadings due to market frictions should be reduced; a commoditized market could allow risks that have not traditionally attracted insurers or reinsurers, such as deferred annuity longevity risk contracts. A standardized risk classification system and index-based instruments will enable more efficient risk management solutions, in particular allowing more efficient balancing of longevity and mortality risk and reducing capital demands.*

*...For a commoditized market to develop, there needs to be a standardization of terms for the writing of financial instruments. Central to that will be the development of a set of widely accepted and accessible reference indices that would mimic the movements on the risk cedants' balance sheets. Index-linked instruments would be highly tradable and could protect cedants from extreme outcomes; they would also allow risk traders to act on their sentiment to future longevity risk. Innovative approaches to structuring financial instruments need to be developed that are attractive to both risk cedants and risk takers, in particular, instruments that reduce the time horizon of traditional indemnity swaps (such as those using commutation mechanisms) are needed to attract capital market investors. Shrinking the margins of dealers in a commoditized market could help to increase returns. Articulating the potential capital benefits of pairing longevity and mortality risk, or the diversification effect of longevity with key financial risks could help engage investors with the potential returns.*

*... Despite some previous false starts for the commoditized longevity market, it feels like the stars may finally be aligning. Over the last few years there has been real concern in the reinsurance community about a capacity crunch if the projected annual market demand materializes. Pension fund consolidators and the success of streamlined longevity swap contracts are bringing smaller pension funds into the de-risking market and new ideas about structuring financial instruments to address the key obstacle of shorter term contracts have now been developed. Players in the market such as Longitude Exchange and Club Vita are working to standardize models and index data to get everyone talking the same language.*

> *For a market to develop, timing of many factors need to align. Maybe that is what's happening right now.*[332]

An additional factor is the aligned understanding of longevity risk, especially in the UK. As Song et al (2023) point out: 'The UK actuarial community has relatively easy access to credible mortality data and mortality improvement studies (e.g., the UK CMI model). Accessibility to quality population mortality data is crucial to balancing the information asymmetry between insurers (who have relatively smaller, more volatile portfolios) and global reinsurers (who have the capability to perform credible longevity studies with their large data repository and carry significant volumes of offsetting mortality risk from group life, catastrophe and other business). This free flow of information has created an unprecedented level of alignment of views on longevity risk among all UK PRT market participants, which in turn has helped the industry in setting an effective "market price" for that risk via longevity swaps'.[333]

Hedge funds (with assets of $4.13trn[334] in June 2022) and private equity (with assets of $7.97trn) could be attracted to this sector since the financial instruments being developed look like alternative fixed-income products with which they are already familiar. However, for them to commit capital, there needs to be much greater liquidity – which is where a trading platform like Longitude Exchange comes in.

Avery Michaelson, CEO of Longitude Exchange, argues that:[335]

> *In order for hedge funds and other institutional investors to get involved in the longevity market, they need a marketplace. Currently, transactions are brokered in an over-the-counter process using transaction formats that aren't well suited to the investment criteria of these players. These investors benefit from a certain level of commoditization of transactions, something which can be addressed with index-based transaction formats. By basing transaction pay outs on general-population mortality data, information asymmetries can be removed along with much of the analytical complexity involved in pricing and risk analysis.*
>
> *Rising interest rates have further accelerated pension de-risking, fuelling greater than ever demand for capital. Fortunately, there are already a number of ILS Funds with experienced life risk teams prepared to commit capital to this space. They will be joined by a much broader range of institutional investors as deal flow and liquidity materialize.*

---

[332] Erik Pickett (2022) If Longevity Risk is an Asset Class, How Do We Make It More Tradeable?, *Life Risk News*, 13 July; https://liferisk.news/if-longevity-risk-is-an-asset-class-how-do-we-make-it-more-tradeable/

[333] Paul Song, Patricia Nguyen, Rey Malile and Mark Spong (2023) Managing Longevity Risk: A Solution to Consider, *Reinsurance News*; https://www.soa.org/sections/reinsurance/reinsurance-newsletter/2023/february/rsn-2023-02-spong/

[334] According to data and analytics provider Preqin.

[335] Quoted in Greg Winterton (2023) Is a Digital Exchange the Solution to the Investor Participation in Longevity Risk Transfer Conundrum?, *Life Risk News*, Volume 2, Issue 2, February; https://liferisk.news/is-a-digital-exchange-the-solution-to-the-investor-participation-in-longevity-risk-transfer-conundrum/

*There are around $100trn of longevity linked liabilities, globally. And every year of unanticipated life expectancy adds around 5% to liabilities. So, if estimates are off by three years, longevity risk could cause $15trn of unfunded liabilities. The enormous quantum of this risk points to the need for capital markets participation. It's only a matter of time before longevity risk is recognized as its own asset class.*

**2023: Longevity 18**

The eighteenth conference (*L18*) was held at Bayes Business School on 7-8 September 2023. It was hosted by the Pensions Institute.[336]

The year opened well for the financial strength of the UK's remaining 5,000 pension schemes with the PwC Buyout Index showing a surplus of £245bn and the Low Reliance Index showing a surplus of £380bn.[337,338] This indicated another bumper year for the PRT market, with a record-breaking £21.2bn of buy-ins and buy-outs completed in the first half of 2023, £50bn for the whole year, and a total of 226 transactions completed during the year.[339] The largest providers were Rothesay (26% of the market), L&G (24%), and PIC (14%).[340] In addition, £10.3bn in longevity swaps were executed during the year: the BT Pension Scheme (£5bn), Marsh McLennan Companies (MMC) UK Pension Fund (£2bn), the Yorkshire and Clydesdale Bank Pension Scheme (£1.6bn) and the Nationwide Pension Fund (£1.7bn). Pension schemes were also beginning to consider using longevity swaps to hedge bulk annuity pricing, i.e., to reduce the risk of bulk annuity prices moving against the scheme. Further, many schemes have 'novated' longevity swaps to bulk annuities.[341]

[336] The conference proceedings for *L18* were published in 2025 in the *European Actuarial Journal.*

[337] November data. The Low Reliance Index assumes schemes invest in low-risk, income-generating assets like bonds, implying a low risk of calling on the sponsor for further funding. The resilience of pension schemes to short term market shocks is something the Pensions Regulator has highlighted in its draft Code of Practice on scheme funding. As a minimum, TPR expects trustees to model and 'stress test' the impact of the kind of event that might occur once every six years on their scheme's assets and liabilities. In contrast, insurance companies need to demonstrate that they can withstand at least a one-in-200 year stress scenario; https://www.pensionpolicyinternational.com/pension-scheme-consolidation-expected-to-continue-into-2024/

[338] The net buyout surplus to scheme sponsors increased by around £25bn as a result of a change to the surplus refund tax announced the UK Chancellor of the Exchequer in his Autumn Statement in November 2022; https://www.pensionpolicyinternational.com/pension-scheme-consolidation-expected-to-continue-into-2024/

[339] https://www.ipe.com/analysis/uk-pension-schemes-concerned-over-insurer-capacity-as-they-approach-endgame/10069778.article; https://www.pensionpolicyinternational.com/pension-risk-transfer-growth-fuels-uk-insurance-rating; https://www.reinsurancene.ws/record-breaking-year-for-pension-risk-transfer-market-in-2023-legal-general; https://www.ipe.com/analysis/db-schemes-indicate-growing-preference-for-retaining-assets/10127774.article

[340] https://www.pensionsage.com/pa/New-entrants-bolster-pension-risk-transfer-market-volumes-in-2023.php

[341] In the first two cases, these were second swaps; https://www.wtwco.com/en-gb/insights/2024/01/what-happened-in-the-longevity-swap-market-in-2023

The market also attracted new entrants.[342] For example, in May, M&G, the global asset manager, announced its intention to enter the bulk annuity market, via its wholly-owned subsidiary the Prudential Assurance Company Limited (UK),[343] to focus on bespoke deals for larger schemes.[344] In October, Resolution Life announced that its Bermudian-based reinsurer, Resolution Re, would enter the market.[345] In November, the Royal London Mutual Insurance Society Limited entered the market.[346]

Existing insurers were also scaling up by employing extra staff, enhancing technology, extending assets and streamlining internal processes. In August, a survey by Standard Life found that 90% of DB pension scheme trustees anticipated approaching an insurer in the next five years about a potential bulk annuity deal.[347] In October, LCP estimated that 1,000 schemes (20% of the total with assets of £275bn out of a total of £1.4trn for DB schemes) were fully-funded on a buy-out basis, while a further 1,250 schemes would reach full funding on a buy-out basis within the next five years. Transfers over the next five years were projected to be £360bn, compared with £155bn over the previous five years.[348]

Despite the new entrants and the increased efficiency of incumbents, there was concern that there would be insufficient capacity in the insurance industry to meet this increase in demand. A particular concern was the shortage of skilled people to meet the growth in the market. Andy McAleese, MVP, Longevity, Europe at Pacific Life Re argues: 'The real constraint in terms of the amount of deals we can do is people. PRT is quite a complex world, transactions are quite challenging to price, structure and execute, they involve a lot of parties, and they are time consuming. There is quite a limited pool of specialist people that can do this, and we're all looking for the same people, and that's a real impediment to growth'.[349] In October, a survey by Standard Life found that 20% of schemes were worried about a lack of insurer capacity or interest.[350] LCP found that insurers were becoming more selective with a 20% reduction in the proportion of insurers that agreed to provide a quotation, while the market for sub-£100m transactions had tightened, with most insurers

[342] https://www.ipe.com/news/uk-sees-record-212bn-transferred-to-insurers-in-first-half-of-2023/10069494.article
[343] Prudential (UK) for short.
[344] M&G Prudential was set up as an asset manager in 2017 as one part of the restructuring of Prudential's UK businesses. The other part included the transfer of £12bn worth of legacy annuity business to Rothesay Life by the end 2019, as previously discussed; https://www.ipe.com/news/mandg-returns-to-uk-bulk-annuity-market/10069007.article
[345] https://www.ipe.com/news/resolution-life-enters-uk-buyout-market/10069742.article
[346] https://www.ipe.com/news/royal-london-kicks-off-entry-into-uk-bulk-annuity-market/10072130.article
[347] https://www.ipe.com/majority-of-db-schemes-expect-to-approach-an-insurer-about-de-risking-within-five-years/10068188.article
[348] https://www.ipe.com/news/uk-sees-record-212bn-transferred-to-insurers-in-first-half-of-2023/10069494.article
[349] Quoted in Greg Winterton (2023) Change in approach a necessity to combat human capital challenges in uk pension risk transfer market, Life Risk News, 12 July 2023; https://liferisk.news/change-in-approach-a-necessity-to-combat-human-capital-challenges-in-uk-pension-risk-transfer-market/?utm_campaign=life-risk-news-volume-2-issue-7-july-2023
[350] https://www.ipe.com/analysis/uk-pension-schemes-concerned-over-insurer-capacity-as-they-approach-endgame/10069778.article

requiring exclusivity below £25m.[351] Nevertheless, pricing remained competitive for well-prepared schemes and LCP felt that insurers were rising to the challenge, and despite short-term resourcing pressures, were confident about their capacity to meet the increase in demand in the coming years.[352]

In January 2023, the UK Prudential Regulation Authority wrote to UK insurance companies warning them that: 'In light of the multiple external uncertainties facing insurers, it is important that firms take proactive steps to assess the adequacy of their risk management and control frameworks. Firms should be able to respond to market and credit risk conditions different from those that prevailed for a long time. Firms need to be prepared for novel risks, changes in risk correlations and increases in distressed assets. We expect firms to assess their credit and counterparty credit risk management capabilities in light of widening credit spreads, rating downgrades, and defaults. … We are paying close attention to whether the continued high level of longevity reinsurance and the emergence of the more complex "funded reinsurance" in the UK life market reduce the protection UK policyholders should have, beyond the risk tolerance. In particular, we see the potential for offshored counterparty concentration risk to arise from rapidly growing levels of reinsurance. These concentrations can arise for firms individually and for the sector as a whole. We expect UK authorized firms to consider their compliance with the Prudent Person Principle (PPP) for the risks associated with their reinsurance activities. Insurers need to consider the reinsurer's resilience over the whole duration of the exposures, as well as the potential impact from a mass recapture event where large concentrations to a small number of counterparties exist. Our own work on counterparty and concentration risk will examine the need for policy action on reinsurance structures and limits, to mitigate systemic risks to policyholders'.[353] In June 2023, the PRA wrote again to UK insurers on the issue of funded reinsurance. It accepted the moderate use of funded reinsurance, but remained concerned about the possibility of too many UK DB assets and liabilities being moved out of the UK and hence outside of the jurisdiction of the UK Pensions Regulator or PRA.[354] In November 2023, the PRA suggested that life insurers should set limits to their exposures to funded reinsurance counterparties as they may be highly exposed to illiquid assets and their investment profiles may be too closely correlated to one another. It also said that they may be placing investments with the reinsurers 'without adequately recognising the inherent uncertainties and risks involved'. It added that in 2025 it would stress test insurers' exposure to funded reinsurance transactions, with the focus on the impact of an insolvency of an overseas counterparty reinsurer in relation to a UK insurer's

[351] https://www.xpsgroup.com/news-views/insights-briefings/bulk-annuity-market-q4-update-trustees-and-pension-scheme-sponsors
[352] https://www.ipe.com/news/uk-sees-record-212bn-transferred-to-insurers-in-first-half-of-2023/10069494.article
[353] https://www.bankofengland.co.uk/-/media/boe/files/prudential-regulation/letter/2023/insurance-supervision-2023-priorities.pdf; Charlotte Gerken (2022) Who's concentrating? Trends in the life insurance sector and the need for strong reinsurance and investment risk management, Bank of England, 20 September, https://www.bis.org/review/r220921f.pdf
[354] https://liferisk.news/the-insurance-regulator-takes-a-look-at-funded-reinsurance/

overall book of pension liabilities and the ability to access collateral in order to maintain the liquidity required to pay pensions.[355]

In April 2023, Charlotte Gerken, executive director for insurance supervision at the Bank of England, warned insurers not to overextend themselves in their efforts to win more business from pension schemes keen to offload risks, conjecturing that UK life insurers could take on more than £500bn of pension liabilities over the coming decade. She said: 'As deals become larger and increasingly focused on buy-outs of complete schemes, we observe BPA writers expanding their risk appetite, sometimes outside their current core expertise. Insurers may be tempted to stretch their capabilities in the short term before leaner years arrive. This is a big structural change in the control of long-term investments in the UK, and the decisions that insurers make now will have long term consequences for the performance and development of the broader economy. Insurers will need to hedge their pension risks with interest rate, cross-currency and inflation swaps, increasing the sector's links to the wider financial system. Insurers therefore need to understand, as they take on these vast sums of assets and liabilities, how they may become greater sources or amplifiers of liquidity risk', reminding insurers of the LDI crisis faced by pension schemes in September 2022 when they struggled to find enough liquidity to pay collateral on their leveraged LDI strategies in response to rapidly rising gilt yields.[356]

The LCP *Longevity Report 2023*[357] argued that 'views on life expectancy need to be re-examined in light of the pandemic, recognizing newly emerging trends. …We are moving into a new era for longevity risk'. The report's key findings which are addressed to pension scheme sponsors and trustees, are:

- *We expect a material slowdown from the pre-pandemic expectation for longevity improvements, primarily due to the ramifications of the pandemic and the pressures on the healthcare system.*[358] *Compared to pre-pandemic levels, a fall in life expectancies of 1 to 2% may be a sensible starting point for most schemes.*
- *In this challenging environment, a robust longevity assessment is best achieved by sewing together actuarial modelling expertise with expert judgement from healthcare professionals. …The gap between life expectancies for the most and least deprived sections of society is widening. This makes tailored analysis to suit your scheme's membership critical for setting longevity assumptions.*
- *Longevity is a significant unhedged risk for many pension schemes. We estimate it is around 25% of the investment risks for a typical scheme. However, in many cases*

[355] https://www.ipe.com/news/bank-of-england-right-to-scrutinise-the-role-of-funded-reinsurance/10071612.article; https://www.bankofengland.co.uk/prudential-regulation/publication/2024/april/pra-business-plan-2024-25

[356] https://www.pensionpolicyinternational.com/bank-of-england-tells-insurers-to-moderate-their-push-into-pensions/

[357] https://indd.adobe.com/view/0fec53c5-dc7b-4171-bf9b-a5a7ec894328

[358] Mortality rates in 2022 were around 4.5% higher than those in 2019, equivalent to around 30,000 additional deaths in the UK. As of January 2023, there were also more than seven million people on NHS England waiting lists, which LCP said was 'worrying given that early consultation and diagnosis can have a significant impact on morbidity and are likely to affect mortality rates over the longer term'.

*the tools trustees and sponsors use to analyze and manage this risk have not changed to reflect this.*

- *Insurers and reinsurers are now making allowances in their longevity pricing for the slowdown in improvements. An informed assessment of longevity is essential for negotiating with them effectively.*
- *Climate change was also expected to present mortality risks for DB schemes – comprising direct drivers such as air pollution and heat-related deaths, and indirect drivers such as increased transmission of diseases, damage to infrastructure, adverse economic consequences, and food supply issues*.[359]

In July 2023, the Continuous Mortality Investigation reported that deaths in the UK in June 2023 were 5% higher than in pre-pandemic June 2019. Across the UK, there have been 200,100 more deaths from all causes than expected from the start of the pandemic to 30 June 2023. Of these, 75,600 were in 2020, 56,600 in 2021, 39,400 in 2022 and 28,500 in the first half of 2023. Pension liabilities would be £8bn lower than three years previously anticipated for schemes going through their triennial valuation between September 2022 and September 2023, according to The Pensions Regulator. Stephen Caine, director of retirement at WTW, argued that the longevity slowdown when combined with the significant reductions in liabilities as a result of rising interest rates over the previous 12-18 months could result in the emergence of larger surpluses and bring forward planned de-risking strategies, such as switches from growth assets to matching assets to lock in gains made and insurance hedging solutions.[360]

In August 2023, TPR updated its guidance on pension superfunds. This included increasing the discount rate and lowering the minimum funding requirement to make pension scheme consolidations more attractive. However, some consultants thought this was 'too little, too late', since the TPR's interim regulatory regime was introduced way back in June 2020, no superfund transactions had so far taken place and there remained continuing uncertainty around the ability of superfunds to extract profits prior to securing members' benefits with an insurer. The updated guidance still favoured superfunds, such as Clara-Pensions, that provide a 'bridge to buy-out' solution with an insurer over those that intend to manage the assets and liabilities until full run-off, like the Pension Superfund.[361]

Just a month later, Edi Truell, the owner of the Pension Superfund, announced that he was closing the pension consolidator, after failing three times to get regulatory approval from TPR which, in turn, failed to produce guidance on how profits generated by superfund investments could be distributed to investors. This made the market 'uninvestable' according to Luke Webster, CEO of the Pension SuperFund, since there is 'no line of sight for an investor as to how they might get their money back'. Steve Webb, the former

[359] This issue is discussed in more detail below.
[360] Pamela Kokoszka (2023) Schemes should stay on top of changing mortality rates, *IPE,* 17 July; https://www.ipe.com/news/schemes-should-stay-on-top-of-changing-mortality-rates/10067876.article?
[361] https://www.ipe.com/news/tprs-updated-guidance-opens-the-door-to-more-uk-superfund-activity/10068307.article?; https://www.thepensionsregulator.gov.uk/en/document-library/scheme-management-detailed-guidance/db-superfunds

pensions minister and now partner at LCP, thought the 'government has had long enough' to agree on the regulatory framework.[362]

Despite the regulatory challenges, in November 2023, Clara-Pensions announced its first pension superfund transaction with the Sears Retail Pension Scheme and the transfer of 9,600 members and £590m in assets, together with the injection of £30m of ring-fenced capital from Clara. Clara said the deal is 'an important stepping stone' in providing the members with a managed journey to an insured buyout, which is expected to take place within the next decade. The £30m funding will act as a loss-absorbing buffer for the scheme on this journey. Isio[363] will administer the scheme.[364] LCP partner and head of endgame innovation Jonathan Griffith said 'Clara represents one of a growing number of new endgame options for pension schemes to embrace as a way to secure benefits for pension scheme members, while also offering enhanced value for other stakeholders'. Matt Cooper, head of alternative pension solutions at PwC, said that superfunds offered schemes with weaker sponsors an alternative solution to enhance the security of members' benefits, and that around 500 DB schemes with 750,000 members and total assets of £100bn may be suitable candidates for entering into a superfund.[365] Andrew Griffith, economic secretary to HM Treasury, called the deal 'an important innovation to British pension provision' and added 'Economies of scale from superfunds can do wonders for pensions, making people's retirement more secure, whilst enabling a broader range of investments in productive finance', in line with the Mansion House Reforms announced in July 2023.[366]

Some organizations have proposed solutions that exploit economies of scale but which go short of full consolidation between pension schemes. For example, Dalriada Trustees has launched an integrated streamlined consolidation service for UK pension schemes to deliver trusteeship, governance and administration, while the schemes retain control of their investments and scheme journey planning.[367] Similarly, Brightwell, the former British Telecom Pension Scheme Management company, has begun offering investment and administrative services to other pension schemes, including the design of mandates and the

[362] https://www.ipe.com/news/uk-financier-pulls-plug-on-commercial-pension-consolidator/10069044.article

[363] Isio is a 2020 spin-off of KPMG UK's Pension Practice which then acquired Deloitte Total Rewards & Benefits in 2023.

[364] https://www.ipe.com/news/clara-pensions-announces-first-superfund-deal/10069874.article

[365] https://www.ipe.com/news/claras-first-superfund-transaction-marks-significant-milestone-for-uk-pension-industry/10069886.article

[366] https://www.professionaladviser.com/news/4142708/superfund-deal-paves-era-db-schemes. The Mansion House Reforms 'will enable [the UK] financial services sector to unlock capital for [the UK's] most promising industries and increase returns for savers, supporting growth across the wider economy. Firstly, the [UK] government is announcing a series of measures to boost outcomes for savers and increase funding liquidity for high-growth companies through reforms to the UK's pension market. Secondly, the government is setting out ways to incentivise companies to start and grow in the UK by strengthening [its] position as a listing destination. And finally, the government is seizing the opportunities of the future by reforming and simplifying [the] financial services rulebook to ensure [the UK has] the most growth-friendly regulation of any financial services centre, without compromising [the government's] commitment to stability'; https://www.gov.uk/government/collections/mansion-house-2023

[367] https://www.ipe.com/news/dalriada-trustees-launches-alternative-pension-consolidation-solution/10071057.article

selection and oversight of investment managers; but again there is no pooling of assets or sharing risks across schemes. Brightwell is seeking partners that share the BT scheme's strategic decision to run the scheme towards self-sufficiency, instead of targeting an insurance buyout.[368]

Other organizations have even argued that the return of pension fund surpluses allows schemes to delay either buying out or selling out to a superfund and instead continue to operate as independent schemes but change their asset allocation in order to enhance investment returns. Van Lanschot Kempen Investment Management estimates that a £1bn DB scheme could lose £200m in value by defaulting to buy-out over the next decade and a further £50m in missed returns. These could be used to benefit members and sponsors, and to 'stimulate the UK economy and promote wider societal benefits'.[369]

A variation on this is capital-backed funding arrangements (CBFA)[370] proposed by the UK Institute and Faculty of Actuaries. The IFoA argues that, despite strong funding, some DB schemes might not believe that an insurance buy-out is best short-term option for a number of reasons, including: not able to buy out liabilities in full with an insurer, concerns around corporate accounting implications, and the potential loss of future surplus that might be used to pay for discretionary pension increases or a defined contribution (DC) section, or be refunded to the company. In comparison with a buy-out or superfund solution where there is a 'step-change in a governance arrangement', a CBFA is principally a time-limited investment decision within the remit of the existing trustee board. A capital provider injects cash into the scheme in order to achieve a specific objective, such as the scheme being fully funded on a self-sufficiency basis in 10 years. In return, the capital provider will work the assets harder in order to generate a higher return than the required threshold by taking greater investment risk. If successful, the capital provider will make a profit. CBFAs can potentially improve member outcomes by, e.g., reducing downside investment risk by underwriting the risk of poor investment returns, pay benefit cashflows with added security while retaining some investment upside and flexibility, and supplement the sponsoring employer's covenant.[371]

Mercer's Pensions Risk Survey in November 2023 predicted that companies with pension fund surpluses could be the subject of restructuring and merger and acquisitions (M&A) activity, with the pension scheme being perceived as a valuable addition to any deal. Mercer senior corporate consultant, Shane Tuohy, said: 'Some [potential company buyers] might be able to take the scheme off company books at little or no cost by securing the benefits with an insurer. Others might choose to run schemes on to extract value. They might offer enhanced security in exchange for an investment strategy which works harder

[368] https://www.ipe.com/pension-funds/benefits-of-travelling-together-in-pensions-wyn-franciss-journey-from-bt-to-brightwell/10070368.article
[369] https://www.ipe.com/news/ifoa-highlights-benefits-of-capital-backed-funding-arrangements/10068493.article
[370] Also known as capital backed journey plans.
[371] https://www.ipe.com/news/ifoa-highlights-benefits-of-capital-backed-funding-arrangements/10068493.article; https://www.xpsgroup.com/news-views/insights-briefings/capital-backed-journey-plans-helping-pensions-schemes-run-for-the-line

or insure part of the risk associated with the DB scheme via the use of a captive vehicle'.[372,373]

Corporate sponsors of pension schemes have also been keen to avoid the problem of a 'trapped surplus' which cannot be easily accessed. Under the UK's DB Funding Regulations,[374] schemes will be required to move to a 'low dependency' basis, where asset returns are matched with pension payments without needing any further contributions from the sponsor. This means that, depending on how far schemes are from low dependency, sponsors will still be required to make contributions into their schemes to prevent funding deficits. But unanticipated changes in, say, interest rates or asset returns could result in a 'trapped surplus'. To avoid this possibility, as schemes approach full funding, some sponsors have agreed with trustees to reduce contributions and instead channel contributions to escrow accounts (cash accounts secured in favour of the trustees with a first-rank priority charge) and reservoir trusts (where the contributions can be invested in higher returning assets). These arrangements are permissible under the DB Funding Regulations.[375]

In December, the UK Financial Reporting Council (FRC)[376] revised its 'Technical Actuarial Standard 300: Pensions (TAS 300)' to reflect developments in the pension industry, in particular increased buyout activity and pension superfunds. Practitioners providing advice to a scheme sponsor contemplating a bulk transfer must consider credible alternatives to the potential transaction, any material impact on the protection provided, material risks to the benefits and any changes to the sponsor's ability to make decisions which affect the level of members' benefits. They must also use models that are calibrated appropriately to reflect the time horizon of projections and have sufficient regard to extreme events. Further, communication on superfund capital adequacy must include an explanation of the uncertainty in the actuarial information.[377] In January 2024, the FRC dropped plans to add explicit ESG (environmental, sustainable and governance) requirements in the UK Corporate Governance Code in order to keep administrative burdens on businesses 'to the minimum necessary'. Instead, the Code sets out more generalized expectations for company boards to monitor and review annually their firm's

[372] https://www.pensionpolicyinternational.com/uk-opportunity-for-buyers-as-db-pension-surplus-growth-continues/

[373] In the November 2023 Autumn statement, the UK Chancellor of the Exchequer reduced the surplus refund tax from 35% to 25% with effect from 5 April 2024.

[374] The DB Funding Code of Practice and the Occupational Pension Schemes (Funding and Investment Strategy and Amendment) Regulations 2024; https://www.gov.uk/government/publications/the-pensions-regulators-defined-benefit-funding-code-of-practice/explanatory-memorandum-to-the-pensions-regulators-defined-benefit-funding-code-of-practice-2024

[375] https://www.pinsentmasons.com/en-gb/out-law/analysis/pension-buy-outs-managing-risk-trapped-surplus-winding-up

[376] The FRC 'regulate[s] auditors, accountants and actuaries, and …set[s] the UK's Corporate Governance and Stewardship Codes. [It promotes] transparency and integrity in business. [Its] work is aimed at investors and others who rely on company reports, audit and high-quality risk management'; https://www.frc.org.uk/about-us/

[377] https://www.ipe.com/news/frc-updates-actuarial-guidance-in-light-of-increased-buyout-activity-superfunds/10070576.article

risk management and internal control framework. The new approach is a 'targeted, proportionate and balanced response to meeting enhanced investor and stakeholder expectations for better governance reporting around risk management and internal controls', but would be less intrusive and prescriptive for company boards, and would help to support UK growth, competitiveness,

It has become increasingly popular for trustees of larger UK pension schemes to buy 'residual risks' insurance cover to protect them against the risk of future claims or disputes following a buy-out of the scheme.[378] The limitation period for making a claim is generally a maximum of six years.[379] The cost of the insurance is typically in the region of 1% of the buy-out premium and typically covers:

- claims from missing beneficiaries;
- a beneficiary proving s/he has a right to a higher level of benefits than those insured;
- a future change in law which reveals that higher benefits should have been secured;
- errors in the data file provided to the insurer; and
- the method used for guaranteed minimum pension (GMP) equalization[380] being found to be deficient.

In an article in *Life Risk News* in December entitled, 'Reinsurance concentration risks point to inevitable future for longevity risk transfer market',[381] Greg Winterton interviewed Avery Michaelson and David Schrager, CEO and CFO, respectively, of Longitude Exchange. They, along with Douglas Anderson and Steven Baxter of Club Vita and Professor Andrew Cairns of Heriot Watt University and Professor David Blake of Bayes Business School, are co-founders of ILMAC (the Index Longevity Market Action Committee) which was set up in May. ILMAC's aim is 'to build a consensus on a framework, ideally a market standard (to be incorporated into regulations such as Solvency UK or Solvency II, and related guidance) for basis risk quantification, combined with a set of principles for the development of an internal model for institutions seeking to use their own approach to basis risk quantification. This is intended to provide clarity on the capital relief that a regulated (re)insurer would achieve from using an index-based hedging structure'.

Michaelson and Schrager discussed the weaknesses of existing hedging arrangements for insurers. Schrager pointed out that 'What insurers are doing – in the UK, the Netherlands, and the US – to avoid being overly exposed to longevity risk is that they transfer it to

[378] https://www.pinsentmasons.com/en-gb/out-law/analysis/pensions-risk-transfer-risks-residual-risk-insurance?
[379] https://www.pinsentmasons.com/en-gb/out-law/analysis/pension-buy-outs-claim-limitation-periods-post-winding-up
[380] Guaranteed Minimum Pension (GMP) equalisation, House of Commons Library, 21 September 2023; https://commonslibrary.parliament.uk/research-briefings/cbp-8427/
[381] Greg Winterton (2023) Reinsurance concentration risks point to inevitable future for longevity risk transfer market', *Life Risk News*, 2(12), December; https://liferisk.news/reinsurance-concentration-risks-point-to-inevitable-future-for-longevity-risk-transfer-market/

reinsurers using longevity swaps. But all of these insurers are hedging their longevity risk with the same limited number of life reinsurers'. Michaelson added 'For all life reinsurers, a natural hedge exists on their balance sheets. The problem is that, as a hedge, it's not quite as effective as it might appear on the surface. When an extreme mortality event, such as Covid, occurs, it is almost certain to produce an offsetting move in a reinsurer's longevity exposures in the form of reduced liabilities. However, in extreme longevity scenarios resulting from broad-based increases in life expectancy, it's less certain to produce significant gains from a reinsurer's mortality business as these are typically shorter duration contracts whose pricing can reset to current expectations about mortality'.

The second problem according to Michaelson is that the scope of the offset is not unlimited: 'The pension risk transfer market is growing at a blistering rate as higher interest rates have accelerated a structural change that's been underway for over a decade. For those reinsurers that have been writing longevity swaps for that whole period, a good portion of the mortality offset has been used up, and the demand for longevity risk capacity is growing faster than for mortality'. Sources of capital outside the insurance industry are therefore needed to support the growth in the global PRT market.

ILMAC was set up in response to these issues and to promote the use of index-based longevity hedging as a way of persuading capital markets investors, such as asset managers and sovereign wealth funds, to take on longevity risk in a format, namely an index, with which they are familiar. With this approach, capital markets investors assume the longevity risk above a certain level based on a general population mortality index. By attracting a large and diversified set of new counterparties, this framework would help to reduce the concentration risk in the exiting market.

Nevertheless, involving the capital markets involves challenges, not least getting regulatory approval for an index-based longevity hedge. This provided part of the motivation for setting up ILMAC. At the time of writing, the committee was preparing a case study that calculates the capital relief a Solvency II insurer could take if it used an index-based hedge and took account of the basis risk that this involved compared with a full-indemnification solution that accounted for the specific mortality experience of the pension scheme being transferred.

Michaelson concluded that 'There could be as much as $500bn of longevity risk transfer demand annually, which is nearly the same size as the entire reinsurance industry. It's not sustainable to move all of the longevity risk globally to just a few balance sheets [those of the small number of global reinsurers] – this could introduce a "too big to fail" situation that regulators are right to be concerned about. The natural solution is to encourage greater involvement from the capital markets'.

Highlights for 2023 in the UK included:

- In February, PIC executed the largest buy-in to date (£6.5bn) with two of the RSA Insurance Group schemes, covering 40,000 members.[382]
- In February, the GKN Group Pension Scheme completed a £513m full scheme buy-in with Just Group, insuring the benefits of some 2,262 pensioners and 1,963 deferred members.[383]
- In March, PIC completed £142m buy-in with the Spirent Communications Staff Pension & Life Assurance Scheme.
- In March, Aviva completed a £34m buy-in with the Chapelthorpe Pension Fund, securing the benefits of the remaining 805 uninsured members in the scheme.
- In March, PIC invested £50m Portsmouth Water to help fund the construction of the Havant Thicket Reservoir, the first major new reservoir in the UK since the 1980s.[384]
- In March, the Shoe Zone Group Pension Scheme completed a £34m buy-in with Rothesay, covering 367 pensioners and 166 deferred members.[385]
- In March, PIC bought a £268m office in Croydon, South London, pre-let to the UK Government Property Agency.[386]
- In April, L&G agreed a £18m buy-in with the Sleepeezee Retirement Benefits Plan, securing the benefits of around 200 retired and deferred members.
- In April, Rothesay secured a £1.4bn buy-in with the Safeway pension scheme, covering 22,500 members.[387]
- In April, Just Group completed a £190m buy-in with the Ibstock Pension Scheme, adding to an existing £340m buy-in policy completing in 2020.
- In May, the Yorkshire and Clydesdale Bank Pension Scheme announced a £1.6bn longevity swap with Zurich Assurance covering 9,000 members, with the longevity risk passed through to Pacific Life Re.[388]
- In May, Aviva completed a £900m buy-in with the Thomas Cook Pension Plan, covering 12,500 members.[389]
- In May, the British Steel Pension Scheme completed a fourth and final buy-in deal worth £2.7bn with L&G, becoming the largest UK scheme to fully insure all its 67,000 retired and deferred members' benefits.[390]

---

[382] https://www.professionalpensions.com/analysis/4077080/rsas-record-breaking-gbp-5bn-means-pensions-risking-market?
[383] https://www.ipe.com/news/uk-roundup-gkn-group-completes-513m-pensions-buy-in-deal-with-just-group/10065404.article?
[384] https://realassets.ipe.com/news/pic-joins-investors-in-portsmouth-waters-uk-reservoir-project/10065631.article
[385] https://www.professionalpensions.com/news/4087363/shoe-zone-scheme-completes-gbp34m-rothesay
[386] https://realassets.ipe.com/news/pic-buys-268m-office-pre-let-to-uk-government-property-agency/10065818.article
[387] https://www.ipe.com/news/buy-in-roundup-safeway-completes-14bn-deal-with-rothesay/10066289.article
[388] https://www.ipe.com/news/uk-bank-pension-scheme-in-16bn-longevity-swap-deal/10066421.article
[389] https://www.ipe.com/news/uk-travel-pension-fund-secures-900m-buy-in-deal-with-aviva/10066537.article
[390] https://www.ipe.com/news/uk-roundup-british-steel-pension-scheme-in-27bn-buy-in-deal/10066690.article?

- In May, Just Group announced a £40m buy-in with the BUT Retirement Benefits Scheme**.**
- In May, Mitchells & Butlers, the pub chain, agreed a £1.2bn bulk purchase annuity transaction with Standard Life covering around 20,200 deferred and retired members. This follows a £650m buy-in for the Mitchells & Butlers Executive Pension Plan with L&G at the end of 2021.[391]
- In June, the Aegon UK pension scheme completed a £160m buy-in with Scottish Widows, covering around 500 members.
- In June, the Harrods Group Pension Plan secured the pension benefit of around 1,900 pensioners and 2,100 deferred members with a £400m buy-in agreement with Scottish Widows.[392]
- In June, Standard Life completed a £80m buy-in with MGM Assurance Staff Pension Plan.
- In June, the Nationwide Pension Fund completed a £1.7bn longevity swap, covering around 7,000 pensioner members, with Zurich Assurance and PICA (as reinsurer of the longevity risk).[393]
- In June, Just Group completed a £94m buy-in with the Mabey Pension Scheme in a record time of three months.
- In July, the Chubb Pension Plan and the Chubb Security Pension Fund, both of which are sponsored by subsidiaries of APi Group Corporation, completed a £1bn buy-in with Standard Life.
- In July, British Telecom (BT) announced that it was planning a £30bn buy-in for its pension scheme which has 60,000 members.[394]
- In July, United Utilities insured £1.8bn in pension liabilities through a buy-in with L&G.
- In July, the Hammerson Group Management Limited Pension and Life Assurance Scheme completed a £390m bulk annuity transaction with Just Group, covering all members of the scheme.
- In July, United Utilities executed a £1.8bn buy-in deal with L&G for its two pension schemes, covering two thirds of the schemes' liabilities.[395]
- In July, Aviva completed a £600,000 buy-out with the Singer & James pension scheme, one of the smallest deals of all time.
- In July, PIC completed a £40m buy-in with the Qantas Airways Limited (UK) Retirement Benefits Scheme.
- In July, Canada Life completed its first-ever deferred member buy-in worth £58m with an undisclosed pension scheme.

---

[391] https://www.ipe.com/news/uk-roundup-mitchells-and-butlers-scheme-in-12bn-buy-in-with-standard-life/10068002.article

[392] https://www.ipe.com/news/harrods-pension-scheme-completes-buy-in-deal-worth-400m/10067147.article?

[393] https://www.ipe.com/news/nationwide-pension-fund-completes-17bn-uk-longevity-risk-transaction/10067303.article?

[394] https://www.ft.com/content/78934baa-e97e-4cd1-b07c-b0957d945f7b

[395] https://www.ipe.com/news/united-utilities-pension-funds-secure-18bn-buy-in-deal-with-legal-and-general/10067906.article?

- In July, Just Group executed a £7m buy-in with the Rannoch Food Group Pension Scheme, covering 46 deferred members and 10 pensioners.
- In July, RGA agreed a £5bn longevity swap with the BT Pension Scheme, covering pensioner liabilities.[396]
- In August, Rothesay completed a £260m buy-in with the Smith & Nephew UK Pension Fund.
- In August, Rothesay also completed a £440m buy-in with the P&O Pension Scheme, covering the retirement benefits of 5,300 members.
- In August, the BT Pension Scheme agreed a £5bn longevity swap with RGA.[397]
- In August, Just Group executed a fifth and final buy-in with the ITB pension scheme (valued at £290m), implying that all of the scheme members' benefits had now been secured.
- In September, the Association of British Insurers (ABI) pension and assurance scheme completed a £18.4m buy-out with Just Group.
- In September, Just Group also completed a £4m buy-out with the KGM pension scheme, covering 14 deferred and 10 pensioner members.
- In September, L&G agreed a £340m buy-in with the Cable and Wireless pension scheme, covering around 1,800 retirees and deferred members.[398]
- In September, M&G executed a £331m buy-in with its own pension scheme (M&G Group Pension Scheme), covering 1,414 pensioners and deferred members, together with the transfer of the scheme's illiquid assets to Prudential (UK) as part of the transaction.
- Also in September, M&G concluded a £286m buy-in with the Northern Bank Pension Scheme, covering 1,917 members.[399]
- In October, the London Stock Exchange (LSE) Group Pension Scheme agreed a £335m buy-in with Standard Life, covering 1,740 members across the LSE and London Clearing House sections of the scheme.[400]
- In October, Canada Life executed a £30m buy-in with the Andrew Sykes Group Pension Scheme, covering around 440 members, including 160 deferred members.
- In October, the British Red Cross pension schemes agreed a £30m buy-in with Aviva, covering 360 members.
- In October, the Bayer Group Pension Plan executed a £280m buy-in with Canada Life, covering the benefits of around 1,300 retirees.[401]
- In October, Resolution Re executed its first transaction by reinsuring the longevity and asset risks associated with the UK pension liabilities (both in payment and

[396] https://www.ipe.com/news/bt-pension-scheme-signs-5bn-longevity-swap-deal/10068085.article?
[397] https://www.ipe.com/bt-pension-scheme-signs-5bn-longevity-swap-deal/10068085.article
[398] C&W had previously executed buy-ins with Prudential in 2008 and with L&G in 2017 and 2019; https://www.ipe.com/news/cable-and-wireless-superannuation-fund-complete-340m-buy-in-deal/10069038.article
[399] https://www.ipe.com/news/northern-bank-pension-scheme-secures-benefits-of-nearly-2k-members/10069079.article
[400] https://www.ipe.com/news/london-stock-exchange-pension-scheme-in-335m-buy-in-with-standard-life/10069419.article
[401] https://www.ipe.com/news/bayer-group-pension-plan-in-280m-buy-in-with-canada-life/10069715.article

deferred) of a UK-regulated insurer, thereby extending funded reinsurance capacity for UK PRT writers.[402]

- In November, Aviva agreed a £80m buy-in with the Rotork pension scheme, securing the benefits of 406 pensioners and dependants.
- In November, Just Group completed a £32m buy-in with the Air France (UK) Pension Scheme, covering around 200 members.
- In November, PIC invested £50m to develop 125 affordable and shared ownership homes in partnership with residential developer London Square, in order to generate secure low-risk, inflation-linked cashflows to pay its pensioner policyholders. PIC has invested around £4bn in this sector since 2012.[403]
- In November, Just Group invested £350m in UK real estate and social infrastructure, including around 100 healthcare facilities that provide specialist care for patients with high acuity caring needs and childcare centres. These assets also generate long-dated, inflation-linked cashflows.[404]
- In November, Deutsche Bank's UK pension scheme completed a £500m buy-in with L&G, covering 2,000 members, and taking the scheme's total buy-in to £1.5bn, around half of the total liabilities.[405]
- In November, the Marsh McLennan Companies (MMC) UK Pension Fund executed a longevity swap covering £2bn of liabilities for around 14,500 pensioners. The longevity risk was insured via a captive Guernsey insurance cell and immediately reinsured with Munich Re through the same Mercer Marsh longevity captive solution used in 2017. This was the first longevity swap to include active members and was also the second largest UK pension fund swap to cover more non-pensioner members than pensioners. Virtually all the fund's DB section longevity risk had now been insured.[406]
- In November, the Co-operative Pension Scheme agreed a £4bn buy-in with Rothesay, covering around 50,000 members, including 17,655 pensioners and dependants as well as 31,896 deferred members.[407]
- In November, the Boots Pension Scheme completed a £4.8bn buy-in with L&G, covering all 53,000 retirees and deferred members. This is the UK's largest single transaction of its kind by premium size and, for L&G, the largest single transaction by number of members. Boots agreed to pay £670m in additional contributions.[408]

---

[402] https://www.resolutionlife.com/news-and-insights/resolution-re-announces-first-uk-prt-reinsurance-transaction/

[403] https://realassets.ipe.com/news/pic-invests-50m-in-uk-affordable-and-shared-ownership-homes-project/10069995.article

[404] https://realassets.ipe.com/news/just-group-invests-350m-in-uk-real-estate-with-focus-on-social-infrastructure/10070026.article

[405] https://www.ipe.com/news/deutsche-bank-uk-pension-scheme-completes-500m-buy-in-with-legal-and-general/10070007.article

[406] https://www.ipe.com/news/mmc-uk-pension-fund-completes-first-active-member-longevity-swap/10070069.article

[407] https://www.ipe.com/news/co-op-pension-fund-insures-remaining-4bn-of-liabilities/10070254.article

[408] https://www.ipe.com/news/boots-pension-scheme-completes-largest-single-transaction-with-landg/10070257.article

- In November**,** Askews Retirement Scheme completed £11m buy-in with L&G**,** covering the benefits of all 86 scheme members.
- In November, Rothesay agreed a £2.7bn full scheme buy-in with the Thales UK pension scheme, covering around 16,000 members, including 10,512 pensioners and dependants, and 5,915 deferred members.[409]
- In November, the Vector Pension Scheme completed a £114m buy-in with Standard Life, covering all 1,800 members.[410]
- In November, Royal London completed a buy-in with Royal Liver valued £246m, covering all the benefits of 3,000 current and deferred pensioners.[411]
- In December, the Superior Pension Fund executed a £10m bulk annuity deal with Just**,** insuring the pension liabilities of 78 members.
- In December, PIC announced it had provided a secured loan of £60m to enable the MHS Homes Group to increase its stock of social houses.[412]
- In December, PIC completed a £65m full buy-in of the Chemring Group Staff Pension Scheme**.**
- In December, Just Group and Macquarie Asset Management invested £400m in notes related to a portfolio of 55 commercial ground leases relating to Asda supermarket sites in exchange for a 'high-quality, long-term income stream from ground lease payments'.[413]
- In December, the Westminster Abbey pension scheme completed a £25m full-scheme buy-in with PIC**.**
- In December, the St Paul's Cathedral pension scheme agreed a £18m full scheme buy-in with Aviva.
- In December, the NICEIC (or Electrical Safety First) Pension Scheme did a £66m full buy-in with Just Group, securing the retirement benefits for 237 pensioners and 154 deferred members.
- In December, the Haag-Streit UK pension scheme completed a £18m full buy-in with Aviva.
- In December, the Hyde Housing Association pension scheme secured a £60m full buy-in with Just Group.
- During the year, Canada Life completed its first deferred member buy-in – the deal was valued at £58m and covered around 300 deferreds and a further 270 pensioners.[414]

[409] https://www.ipe.com/news/thales-pension-scheme-secures-27bn-buy-in-with-rothesay/10070427.article
[410] https://www.ipe.com/news/vector-pension-scheme-completes-buy-in-with-standard-life/10071615.article
[411] https://www.ipe.com/news/royal-london-kicks-off-entry-into-uk-bulk-annuity-market/10072130.article
[412] https://realassets.ipe.com/news/pic-expands-lending-in-uk-social-housing-sector-with-30m-investment/10070518.article; *Insurance Asset Management*, 11 December 2023.
[413] https://realassets.ipe.com/news/macquarie-and-just-group-enter-400m-ground-lease-financing-with-asda/10070645.article
[414] https://www.xpsgroup.com/news-views/insights-briefings/bulk-annuity-market-q4-update-trustees-and-pension-scheme-sponsors

- At the end of the year, Resolution Re reinsured the market and longevity risks of around 90,000 policyholders of an unnamed UK insurer, totalling around £2bn individual in-payment UK annuity liabilities.[415]

There were a number of significant international developments outside the UK in 2023.

US corporate pension plans were on average fully funded for the first time in 15 years (103.5% in June 2023[416]). This was largely because the average discount rate used to value plan liabilities was 5.25%, well above the 2.88% rate used a year before. The increase is explained by the Federal Reserve's increase in the Federal Funds Rate to 5.25% to 5.50% in July in order to control inflation. This was expected to increase pension risk transfer transactions, whether a full termination or lift-out of a select population of retirees and beneficiaries. Corporations also benefited from lower buy-out premiums charged by insurance companies. According to Milliman, the estimated average premium was 99.3% as of March 31. Another contributing factor was the higher premium charged by the Pension Benefit Guaranty Corporation (increased by 9% in 2023 and 5% in 2024 to $101 per participant[417]) which can be avoided following PRT.[418] MetLife's 2023 Pension Risk Transfer Poll in October found that 90% of DB plans expected to fully transfer all their liabilities in an average of 4 years. The main reasons given were inflation (49%), increases in the volume of retirees, market volatility and rising interest rates (all 42%) and attractive annuity pricing (35%). The majority of respondents (55%) said they planned to divest of all their liabilities through multiple transactions, while the rest said they would use a single transaction.[419] While they were waiting to divest, a large number of schemes (44%) were planning to amend their liability-driven investment strategies to improve downside risk protection, according to a survey sponsored by Franklin Templeton.[420] During the first half of 2023, a record $22.5bn in transactions were completed, with $45bn for the whole year. There were a total of 773 transactions, of which 453 were terminations, 310 lift-outs and 10 buy-ins, valued at $12.4bn, $28.7bn and $3.9bn, respectively.[421] Pricing was competitive, close to the value of liabilities that plan sponsors are holding on their balance sheets.[422]

Highlights for 2023 in the US included:

---

[415] https://www.resolutionlife.com/news-and-insights/resolution-re-announces-new-reinsurance-transaction-in-the-uk/; *Insurance Asset Management*, 17 January 2024.
[416] https://www.pensionpolicyinternational.com/global-pension-risk-transfer-monitor-record-h1-transaction-volumes-in-uk-and-us/
[417] https://www.pbgc.gov/prac/prem/premium-rates
[418] https://www.ai-cio.com/news/pension-risk-transfers-poised-for-2nd-strongest-year-ever
[419] https://www.pensionpolicyinternational.com/90-of-u-s-companies-with-db-plans-looking-for-exits-via-prt-metlife/
[420] https://www.pensionpolicyinternational.com/us-study-finds-healthier-funding-status-for-db-plans-raising-interest-in-ldi-strategy-reviews/
[421] https://www.pensionpolicyinternational.com/us-pension-risk-transfer-market-expected-to-see-10-billion-in-q3-deal-volume/; https://www.pensionpolicyinternational.com/u-s-prt-transactions-hit-all-time-high-in-2023-aon/
[422] https://liferisk.news/still-plenty-of-capacity-for-growth-in-robust-us-prt-market/

- In May, AT&T Inc announced the third-largest US pension risk transfer to date via its purchase of group annuity contracts from two Athene Holding subsidiaries (Athene Annuity & Life Co. and Athene Annuity & Life Assurance Co. of New York) covering the $8.1bn pension liabilities of 96,000 AT&T plan members and beneficiaries.[423]
- In June, Legal & General Retirement America (LGRA) and RGA agreed a $309m pension risk transfer transaction with PPG, a Fortune 500 paint manufacturer.
- In June, Fidelity Investments registered Soteria Reinsurance in Bermuda in order to 'focus on affiliated reinsurance of US Retail Fixed Annuities and Pension Risk Transfer Opportunities of existing and new Fidelity Investment Life Insurance Company (FILI) business'.[424]
- In August, Prudential Financial announced the transfer of around $1bn in pension liabilities from PSEG, a utilities provider, for 2,000 participants. The deal is a 'retiree only lift-out', with only the liabilities of these retirees being annuitized.[425]
- In November, MetLife completed a risk transfer transaction with Global Atlantic Financial Group, a retirement and life insurance company. The deal contributed to the run-off of MetLife's closed-block of US retail business, representing $19bn of statutory reserves. MetLife will remain as administrator and service provider for the reinsured policies and MetLife Investment Management will also manage a significant amount of the assets for the next five years.[426]

One of the most significant events during the year was establishment in September of Prismic Life Re, a licensed Class E Bermuda-based life and annuity reinsurance company. Prismic is backed by $1bn in equity capital, with the lead investors being Prudential Financial and Warburg Pincus, with equity holdings of 20% and 15%, respectively. Prudential plans to reinsure to Prismic a block of structured settlement annuity contracts[427] with reserves of approximately $10bn. Prudential's obligations to the holders of these annuities will remain unchanged and Prudential will continue to administer the contracts. Prismic will be a strategic reinsurance partner for Prudential in the years ahead. PGIM (Prudential Global Investment Management) and Warburg Pincus will provide asset management services to Prismic: PGIM's expertise is in public fixed income, private credit and real estate, while Warburg Pincus specialises in private market investments. Prismic will become a client of PGIM Portfolio Advisory, a newly established affiliate within PGIM that combines asset-liability management expertise with portfolio strategy and asset allocation to deliver integrated solutions across public and private asset classes. Prismic's

[423] https://www.pensionpolicyinternational.com/us-rising-interest-rates-put-corporate-pension-plans-on-end-game-pat/; https://www.pensionpolicyinternational.com/us-pension-risk-transfer-market-off-to-strong-start-this-year/

[424] https://www.pensionpolicyinternational.com/fidelity-investments-forms-retail-annuities-and-pension-risk-transfer-focused-reinsurer/

[425] https://www.ai-cio.com/news/prudential-closes-1-billion-prt-deal-with-pseg/

[426] https://www.bloomberg.com/press-releases/2023-11-16/metlife-completes-risk-transfer-transaction-with-global-atlantic-financial-group

[427] A structured settlement annuity provides regular tax-free payments and is used in cases of personal injury and legal settlements, such as workers' compensation, medical malpractice and wrongful death; https://www.annuity.org/structured-settlements/

first CEO is Amy Kessler, who was the founding leader of Prudential's international reinsurance business.

Charles Lowrey, chairman and CEO of Prudential Financial, said: 'This unique reinsurance platform will play an important role in our vision to be a global leader in expanding access to investing, insurance, and retirement security for people around the world. Prismic will enhance our ability to address the evolving needs of our insurance customers and clients while continuing to meet our obligations to policyholders. It represents a formidable combination of industry-leading expertise, global capabilities, and the backing of two of the world's leading insurance and asset management firms'.[428] This event is significant because it is one of the first big attempts to bring third-party capital into reinsurance industry in order to sustain its extraordinary recent growth.

At the same time, the increasing involvement of private equity (or private capital) firms (sometimes in conjunction with other investors, such as sovereign-wealth funds) has attracted the attention of US politicians and regulators. McKinsey reported in 2022 that the five largest PE firms by assets have investments in life insurers with exposures ranging from 15 to 50% of their total assets under management and that private investors owned in excess of $900bn of life and annuity assets in Europe and North America.[429] In August 2023, Senator Sherrod Brown, Chair of the US Senate Committee on Banking, Housing, and Urban Affairs, started to question the role of PE in insuring pension payments.[430] The Federal Insurance Office (FIO) pointed out in a response to Senator Sherrod Brown that 'As private markets have expanded over the last decade, far outpacing the growth of public markets, private equity firms have reshaped their business models and increased involvement in the life insurance sector. Previously, the focus of private equity was largely on buy-outs. Now, some private equity firms are increasingly pivoting their business objective to the private credit market'.

The McKinsey report points out that PE has been involved in the US insurance industry since at least 1967 when Berkshire Hathaway acquired National Indemnity. One of the key attractions is that ownership of a life insurer gives access to 'permanent capital', funds which do not have to be returned to investors on a specific timetable or at all. This permanent capital therefore saves PE investors time and effort on fundraising and offers them the flexibility to invest 'at times, like a crisis, when other forms of capital can become scarce'. Another attraction is that the returns on PE shareholders' equity can be increased by between 4-7 percentage points annually (to between 10-14%) by applying their investment management capabilities to earn alpha on some asset classes, such as asset-backed securities (primarily collateralized loan obligations) and private loans. Further, the relatively high (ten times) asset-to-equity ratio typical of insurers amplifies the impact of strong investment performance. The report says that 'The core attraction is straightforward.

[428] https://news.prudential.com/prudential-financial-inc-and-warburg-pincus-announce-launch-prismic-life-re.htm
[429] https://www.mckinsey.com/industries/private-equity-and-principal-investors/our-insights/why-private-equity-sees-life-and-annuities-as-an-enticing-form-of-permanent-capital
[430] https://www.brown.senate.gov/newsroom/press/release/sherrod-brown-continues-push-private-equity-firms-involvement-insurance-industry

The balance sheets of life and annuities companies [are one form of permanent capital and] are well stocked with assets…but until payout, these assets need to be invested to generate returns. And in many cases, the cost of servicing the liabilities is significantly lower than the potential investment return. The spread represents an attractive margin'.

However, Charles Decker, a researcher at the Unite Here trade union, has argued that 'The whole private debt sector has grown hand-in-hand with the low interest rate environment and there are reasons to be concerned about an asset class which has not been tested by either a period of prolonged high interest rates, or a major recession. But [our] greatest concern is just how opaque these assets are, it's very difficult to find out exactly what these private equity-backed insurers are investing in'.[431] There is also concern about the 'maturity wall' of low-grade corporate bonds that were issued during the period of ultra-low interest rates and which will mature over the next few years ($38bn in the US in 2024 and increasing to $235bn in 2028). These bonds will need to rolled over in the world of much higher interest rates that central banks have introduced to control inflation. But according the Federal Reserve, 10% of US companies have a so-called 'zombie' status and are unable to cover their interest expenses from operating income. A report by BCA (Bank Credit Analyst) Research found that 'Zombie companies… are multiplying [and] are highly sensitive to surging borrowing costs'.[432] Joe Engelhard, Senior Counsel, US Policy & Regulation at the Alternative Investment Management Association (AIMA), the global trade body for the private equity industry, responded to criticisms like this by arguing that 'In the US, the pension risk transfer market is regulated at both the federal and state levels, and insurers have a great track record over many decades of providing benefits to annuitants'.[433]

In December 2023, the IMF published a Global Financial Stability Note[434] on the growing trend of private equity investments in the life insurance industry. It noted that many PE firms have opened offices in Bermuda, where most of the long-term insurance gets reinsured. Apollo, KKR and Carlyle, for example, manage half of all long-term reinsurance assets on the island. It added that, while Bermuda's solvency regime has been granted equivalent status to those in the US and UK, 'it appears possible to gain recognition for the premium earned on illiquid investments when determining the discount rate for valuing technical provisions more often than in other regimes': allocations to illiquids by PE-influenced reinsurance in Bermuda averages 20% of portfolios compared with 6% for a sample of 50 major insurers globally.

The median solvency ratio of Canadian corporate DB pension plans was 119% at the end of June 2023, with 85% of the plans in surplus on a solvency basis. In order to protect these surpluses and de-risk their portfolios, plan managers were buying annuities from life

[431] https://liferisk.news/spotlight-falls-on-us-life-insurers-private-debt-investments
[432] https://www.ai-cio.com/news/weak-companies-low-yielding-bonds-set-to-hit-maturity-wall/
[433] https://liferisk.news/spotlight-falls-on-us-life-insurers-private-debt-investments
[434] Fabio Cortes, Mohamed Diaby and Peter Windsor (2023) Private Equity and Life Insurers, *International Monetary Fund Global Financial Stability Note*, 19 December 2023;
https://www.imf.org/en/Publications/global-financial-stability-notes/Issues/2023/12/13/Private-Equity-and-Life-Insurers-541437

insurance companies to transfer pension risk (around C$8bn annually), increasing liability-driven investments, and swapping shorter-dated for longer-dated bonds to increase the maturity matching with liabilities.[435] In 2023, there were 190 PRT deals totalling C$7.8bn (with an average size of C$40mn).[436]

In March, Legal & General entered the Dutch buy-out market in partnership with Dutch insurer Lifetri to arrange future buy-outs with pension funds that do not want to make the transition to the new defined contribution system and would provide 'insurance-based, capital-backed guarantees for members'. Lifetri had previously executed only one buy-out deal, namely a €850m buy-out of the pension benefits of Pensioenfonds Allianz in 2020. To date, buy-outs have not been common in the Netherlands. In 2022, there was just one buy-out, with the closed Dutch pension fund of A.C. Nielsen executed by Zwitserleven.[437]

In December, NN Life (a subsidiary of NN Group) completed two transactions to transfer the full longevity risk associated with €13bn of pension liabilities across 300,000 policies in the Netherlands to Prudential Financial and Swiss Re.[438] The reinsurance agreements will continue until the portfolio has run off and do not impact the services and guarantees that NN provides to its policyholders. The aim of the agreements is to reduce NN's exposure to longevity risk and hence strengthen NN's capital position. David Knibbe, CEO of NN Group, said: 'The capital uplift and economics from these transactions are very attractive compared to the limited impact on operating capital generation. It underscores our efforts to continually look for value creating opportunities, reduce longevity risk in the Dutch market, and actively manage our balance sheet'. Prior to the transaction, the Solvency II ratios for NN Group and NN Life were 205% and 187%, respectively. Following them, there will be an upfront capital benefit which will increase the Solvency II ratios for NN Group by 8 percentage points and for NN Life by 17 percentage points. The lower risk profile will lead to a limited decrease in operating capital generation for the first five years in the range of €30-35m per year. In the following years, the negative impact will decrease over time in line with the run-off of the portfolio.

**2024**

PRT volumes in 2024 were slightly lower than in 2023, with £48bn of bulk annuity transactions and £790m of longevity swaps, although the total number of transactions was 298, the highest ever. Rothesay wrote the largest volumes at £10.3bn (22% market share), followed by Legal & General on £8.4bn (18% market share) and Pension Insurance Corporation (PIC) on £8.1bn (17% market share). Aviva, Just and Standard Life wrote over £5bn of buy-ins/outs in 2024 (c11% market shares).[439]

---

[435] https://www.ai-cio.com/news/canadian-pension-plans-look-to-annuities-fixed-income-to-preserve-pension-surplus
[436] https://liferisk.news/canadian-pension-risk-transfer-market-set-for-record-year-even-as-interest-rates-fall/
[437] https://www.ipe.com/news/landg-to-enter-dutch-buyout-market-with-lifetri-partnership/10065654.article
[438] https://www.nn-group.com/news/nn-life-completes-two-longevity-transactions/
[439] https://www.ipe.com/news/bpa-transactions-hit-record-number-in-2024/10130316.article

More schemes would be choosing full scheme buy-ins 'as a stepping stone to buy-out', although superfunds would continue to see 'momentum' as part of the market. Further, some schemes might decide to 'pause for thought',[440] as they consider if running-on or delaying a move to buy-out could provide additional value if legislative change makes it easier to extract surplus: 'If this is the case, it's unlikely that these schemes would wish to run unrewarded risks and consequently could look to hedge their demographic risks through the use of longevity swaps'.[441] A survey by Russell Investments found that, despite significant recent improvements in funding (out of total UK DB assets of £1.2trn, around a third of schemes (by value) were in surplus on a buyout basis), nearly a third of schemes had not yet decided on their endgame target and may decide to run on/off; although for those with an endgame target, buy-out is the preferred long-term option.[442] Aon's *Global Pension Risk Survey 2023/24* of UK DB schemes suggested that 55% of schemes had buy-out as their long-term target,[443] with 53% of large DB schemes planning a buy-in or buy-out within the next three years, according to Legal & General.[444]

PRT volume during the year was driven by small schemes (below £100m), for which some insurers had introduced streamlined solutions (sometimes called templated transfer or 'off the shelf' processes), such as: Aviva's Clarity streamlined bulk purchase annuity service for smaller (sub-£100mn) schemes, offering an 'efficient and robust process that enables well-prepared schemes to secure attractive pricing' (April);[445] PIC's small schemes solution, called Mosaic, for sub-£100mn schemes looking to complete a buyout, which offers price monitoring and standard processes and contracts;[446] L&G's Flow solution for sub-£150mn schemes (September); and Just Group's Beacon solution. Sub-£100mn schemes account for 75% of the UK's 5,000 DB pension schemes, and they accounted for 80% of completed deals in 2024.[447] However, the biggest the biggest growth segment was 'micro' sub-£10m schemes, which experienced a 60% year-on-year increase in transaction numbers, making up over 30% of 2024 transactions.

In July, two new companies announced that they were entering the UK PRT market. The first was Canadian financial services firm Brookfield which created Brookfield Reinsurance and filed paperwork with the PRA for approval. The second was Utmost Life and Pensions, previously called Reliance Life until it was bought by the Utmost Group in 2018; it already had 300,000 customers, including former Equitable Life customers. There was also some consolidation in the market: in March, Rothesay bought the £6bn Scottish

[440] In the light of the Mansion House reforms.
[441] https://www.professionalpensions.com/news/4166008/2024-gbp80bn-db-risking-deals-wtw-predicts
[442] https://www.ipe.com/analysis/db-schemes-indicate-growing-preference-for-retaining-assets/10127774.article
[443] https://www.pensionpolicyinternational.com/analysis-2024-to-be-the-biggest-year-for-uk-pension-de-risking/
[444] https://www.pensionpolicyinternational.com/majority-of-u-k-db-plans-looking-for-buy-in-or-buyout/
[445] https://www.ipe.com/news/aviva-launches-streamlined-bulk-purchase-annuity-service-for-smaller-schemes/10072650.article
[446] https://www.ipe.com/news/pic-launches-streamlined-solution-for-small-pension-schemes/10072883.article
[447] https://funds-europe.com/prt-market-in-uk-and-us-set-to-reach-250bn-within-three-years; https://liferisk.news/streamlined-pension-risk-transfer-deals-widen-small-scheme-opportunities/

Widows' in-force bulk annuity portfolio from Lloyds banking group, covering 42,000 annuitants.[448] In total, there were now 11 PRT providers in the UK.[449]

However, a report from Standard Life found that pension schemes' holdings of illiquid assets were delaying PRTs. Standard Life found that 40% of schemes planning to derisk had illiquid assets to offload and consultants reported that issues with such assets had delayed a transaction. This is because they were 'generally not a good fit for insurers' annuity portfolios due to regulatory requirements'. Illiquid assets, like real estate, can often not be sold at short notice without a significant reduction in value as well as the expense of using a broker. However, two new platforms (XPS Group's i Xchange and Isio's Fund Liquidity Option or i-FLO) have been established to help schemes sell their illiquid assets by finding the best price without using a broker. In August, the Britannia Pension Scheme became the first of Isio's clients by selling a £72mn investment in a private credit fund. Other alternatives have been to use the illiquid asset as a premium or deferred premium payment. The insurer uses the asset to back the bulk purchase annuity or uses it somewhere else in its balance sheet (e.g., with-profits fund); this is still a complex, lengthy process and the asset is still sold at a discount, but the discount might be lower than using a broker.[450]

There was a significant innovation during the year, the introduction of the Value Share Bulk Purchase Annuity. In November, an unnamed UK pension scheme executed a £500m Value Share Bulk Purchase Annuity with M&G, in what is believed to be the market's first BPA deal to share value with a corporate sponsor, allowing corporate sponsors to participate in the risk and reward generated from insuring their scheme. Max Koe, associate director of corporate risk solutions at M&G said: 'A lot of sponsors look at their schemes that are overfunded or have a surplus now and think "Well, why don't you run on, maybe stop investing in Gilts, invest in something slightly more attractive, like corporate bonds, and generate a surplus, and then we can share the surplus later down the line". The issue is the trustee. The trustee's main job is to secure the benefits for its members – so what's the incentive for them or for the members? With this proposition, M&G gives trustees and scheme members "ultimate security" as with a BPA transaction. And then what we do on the back end, which the trustee doesn't care about or see, really, is just reinsure some of that risk to the sponsor. The proposition also works for the insurer because by passing some of the risk over to the sponsor, we don't have to hold as much capital as we would with a normal core BPA'.[451]

In February, the Bank of England announced that it would stress test UK insurers on their exposure to reinsurance firms. It said it was concerned that the offshore arrangements involved could be increasing risk to pensioners.[452] In the same month, Hymans Robertson

[448] https://www.ipe.com/news/scottish-widows-and-rothesay-complete-6bn-in-force-bulk-annuity-deal/10072190.article
[449] https://www.pensions-expert.com/Defined-Benefit/Brookfield-and-Utmost-to-enter-bulk-annuity-market
[450] https://liferisk.news/illiquid-assets-a-blessing-and-a-curse-for-pension-schemes-en-route-to-a-bulk-purchase-annuity-solution/
[451] https://www.ipe.com/news/mandg-launches-value-share-bulk-purchase-annuity-with-500m-transaction/10126504.article
[452] *Insurance Asset Management*, 13 February 2024.

released a digital tool called PACE (Plan, Aim, Check, Execute) to help UK DB schemes build and implement a cohesive buy-out strategy. PACE integrates affordability, investment and due diligence considerations to build a robust plan, making the best use of the time leading-up to the transaction to get schemes ready for buyout. In particular, it uses dynamic annuity pricing to let schemes see how close they are to buy-out. At the appropriate time, the Hymans Robertsons risk transfer team will execute the deal.[453]

In April, the Pensions Protection Fund proposed the introduction of a public consolidator, a statutory fund under the management of the board of the PPF. It pointed out that there were £1.4trn assets in DB schemes, 75% of which have assets below £100m. It estimated that up to 2,300 schemes, with 960,000 members and assets of £130bn, could be interested in transferring to a public consolidator. This could unlock £10bn to invest in UK growth assets. Michelle Ostermann, PPF CEO, said: 'International experience shows that pension consolidation can drive better member outcomes and support productive investment'.[454]

In May, the Pensions Regulator released a new three-year corporate plan. At the centre of the plan was consolidation with the regulator working towards an industry with fewer more efficient pension schemes.[455] TPR said: 'We believe that the benefits of economies of scale, strong governance and access to investment expertise in larger, better-resourced schemes will help to drive stronger outcomes for savers'. It also wanted to see an emerging competitive superfunds market that offers 'enhanced security for savers'.[456]

In July, TPR updated its guidance on both the amount of capital and the release of capital from superfunds. Previous guidance stated that when a DB scheme is transferred to a superfund, new capital had to be provided at a level which (taking into account the value of the assets and liabilities of the transferred scheme) would satisfy capital requirements if that pension scheme were considered in isolation (the standalone test). The previous guidance also only allowed capital to be released when benefits were bought out. The new guidance removes the standalone test as long as the superfund as a whole is funded above the level at which capital can be released. If this is the case, capital could be released up to twice a year. TPR also relaxed standard capital adequacy requirements where a pension scheme's sponsoring employer becomes insolvent and the scheme is unable either to afford the buyout of full benefits or to enter a superfund or capital-backed arrangement on full capital adequacy terms. The transaction would have to be in the members' best interests and the level of benefits would have to be materially higher than buying out with an insurer on PPF+ benefits levels, even if the capital adequacy basis is lower. The regulator said its aim was to protect scheme members, while supporting innovation in the market.

---

[453] https://www.ipe.com/news/hymans-robertson-sets-up-digital-tool-to-help-schemes-buyout-journey/10071817.article
[454] https://www.ipe.com/news/ppf-run-pensions-consolidator-could-unlock-10bn-in-uk-investment/10072813.article
[455] https://www.ipe.com/news/tpr-focuses-on-driving-consolidation-in-new-corporate-plan/10073062.article
[456] https://www.ipe.com/news/uk-regulator-committed-to-supporting-further-innovation-in-db-market/10072898.article

The updated guidance was welcomed by Simon True, CEO of Clara-Pensions, as an 'important step forward' for the superfund model, enabling more schemes to access consolidation and ensuring greater security for more members. Iain Pearce, head of alternative risk transfer solutions at Hymans Robertson, argued that the previous guidance had effectively restricted superfunds to being a temporary 'bridge to a buy-out', as with Clara's first transaction. However, the new guidance means that the superfund market is 'truly open for business and innovation'.[457]

In August, the PRA issued a new policy statement giving its expectations on funded reinsurance (FundedRe), following concerns that the current growth in the FundedRe market could, if not properly controlled, lead to a rapid build-up of risks in the sector. The policy statement is targeted at insurers entering into or holding funded reinsurance arrangements as cedants. It outlined its expectations on: the ongoing risk management of funded reinsurance arrangements; the modelling of the solvency capital requirement associated with funded reinsurance arrangements; and how firms should consider the structuring of funded reinsurance arrangements. The PRA said it would monitor closely the volume of FundedRe transacted by firms, any change in the quality of the collateral and the nature of FundedRe counterparties active in the market, and the progress firms make in implementing risk management and control arrangements. It warned that, if firms were not meeting expectations on the risk management practices needed to mitigate the risks FundedRe poses, it would consider whether it was appropriate to take further action. This could include, for example, consideration of explicit regulatory restrictions on the amount and structure of FundedRe, or measures to address any underestimation of risk, or regulatory arbitrage, inherent in these transactions.[458]

In October 2024, a study by Better Society Capital found that pension funds were the most active investors in the UK's social and affordable housing sector, representing just over 40% of the market. The sector was worth £10bn in 2023. Pension funds accounted for 21% of the UK's total social impact investment market, with most of their funds being directed towards social and affordable housing.[459]

In November, the Bank's Financial Stability Report warned of the consequences of the increasing number of private equity firms that have bought the US reinsurers to which UK insurers have transferred some of their risk. PE-backed reinsurers target higher returns via greater risk-taking, often by investing in illiquid private assets. A potential sharp and correlated deterioration in these investments could amplify risks across global insurers, leading to 'asset fire sales' which would disrupt corporate funding markets. Loss of policyholder confidence could also create a liquidity stress. In addition, UK insurers could

[457] https://www.ipe.com/news/uk-regulator-clarifies-capital-release-expectations-for-superfunds/10074899.article

[458] https://www.pensionsage.com/pa/PRA-issues-new-funded-reinsurance-expectations-BPA-market-not-expected-to-be-impacted.php

[459] Endowments and charities were the second biggest social impact investors (14%), followed by asset and wealth managers (13%), high-net-worth individuals and family offices (9%) and government bodies (including local authorities) and banks (both at 8%); https://impact-investor.com/pension-funds-biggest-investors-in-uks-10bn-social-impact-investment-market/

experience falls in solvency ratios that trigger termination of the reinsurance contracts and a recapture event, whereby the original insurer take back the risk. The subsequent increase in capital requirements may force insurers to sell assets at steep discounts to raise cash, exacerbating market stress.[460]

In December, the Prudential Regulation Authority proposed new liquidity reporting requirements for large UK life insurers. This was in response to prominent market stress episodes, such as the 'dash for cash' at the onset of the Covid-19 pandemic in March 2020, and the liability-driven investment (LDI) crisis in September 2022. According to the PRA, these episodes highlighted gaps in the UK insurers' liquidity risk frameworks and in some cases led to strains on liquidity, driven by sharp rises in margin requirements under derivatives contracts. The PRA proposed the collection of timely, consistent, and comparable data on the liquidity positions of large UK life insurers. The information collected is also intended to help firms manage their own liquidity positions and decide on appropriate risk management actions.[461]

In December, SEI and PIC announced a strategic partnership to provide pension scheme trustees with the means to bulk transfer DC pension benefits into the SEI Master Trust as part of their buy-out arrangements. This gives DB scheme members who also have a DC pension component access to SEI's wide range of investment options, thereby enhancing member outcomes, prior to entering a buy-out of their DB component.[462] Also in December, Resolution Life was acquired by Nippon Life for $10.6bn.[463]

Highlights for 2024 in the UK included:[464]

- UK insurers were estimated to represent 85% of the £5bn-£6bn institutional market for commercial ground rents.[465]
- In January, Royal London agreed a bulk annuity deal with the Royal London Group pension scheme valued at £348m. [466]
- In January, the CP Pharmaceuticals pension scheme agreed a £28m full buy-in with Just Group, covering 317 members.[467]
- In January, Just Group completed a £1.5m full scheme buy-in with the Intersil Limited Superannuation Fund.[468]

[460] https://www.bloomberg.com/news/articles/2024-11-29/private-equity-tie-ups-with-insurers-create-risks-boe-says
[461] https://www.bankofengland.co.uk/news/2024/december/the-pra-consults-on-liquidity-reporting-reforms-for-insurers
[462] https://www.ipe.com/news/sei-joins-forces-with-pic-to-facilitate-master-trust-access-for-db-scheme-members/10127839.article
[463] https://www.resolutionlife.com/news-and-insights/resolution-life-announces-acquisition-by-nippon-life/
[464] What is noticeable is the increasing number of small scheme transactions.
[465] *Insurance Asset Management*, 17 January 2024.
[466] https://www.ipe.com/news/royal-london-kicks-off-entry-into-uk-bulk-annuity-market/10072130.article
[467] *Insurance Asset Management*, 4 January 2024.
[468] *Insurance Asset Management*, 12 January 2024.

- In January, the Guilbert UK Retirement Benefits Plan has completed a £140m full scheme buy-in transaction with Aviva, covering all 1,500 scheme members.[469]
- In January, two Unisys pension schemes completed a £300m full-scheme buy-in with Standard Life, covering 2,400 scheme members.[470]
- In January, the Rexam Pension Plan executed a £1.4bn full scheme buy-in with Rothesay, covering around 14,000 members, including 9,790 pensioners and dependants, and 4,330 deferred members.[471]
- In January, an unnamed innovation and technology pension scheme completed a £400m full scheme buy-in transaction with Just Group, covering 2,500 pensioners and dependants and 1,500 deferred members of the scheme.[472]
- In February, the DAS Legal Expenses Insurance Company Limited Pension and Life Assurance Scheme did a £72m full scheme buy-in with Canada Life, covering 444 deferred members and 134 pensioners.[473]
- In February, the Birmingham Chamber of Commerce Pension Fund agreed a £9m full scheme buy-in with Just Group, covering around 100 pensioners and 40 deferred members.[474]
- In February, Just Group entered a £33m real estate ground rent investment in specialist healthcare facilities, via AlphaReal, in order to secure long-dated, inflation-linked cashflows, secured against 33 specialist healthcare facilities providing essential social infrastructure.[475]
- In February, the Vector Pension Scheme completed a £114m buy-in with Standard Life, covering 1,800 scheme members.[476]
- In February, PIC made a £30m debt investment in Northern Ireland's Apex Housing Association, to help fund a social housing development which in return will provide 'low risk, long-term, secure cashflows that match our pension liabilities for decades into the future'.[477]
- In February, the Spar UK Limited Pension Fund completed an £11m buy-in deal with Just Group.[478]
- In March, the Greenhous Group (2015) Retirement Benefits Scheme executed a £19m full buy-in deal with Just Group.[479]
- In March, three Thomas Cook Travel pension schemes completed full-scheme buy-ins with PIC for a total of £50m.[480]

[469] *Insurance Asset Management*, 16 January 2024.
[470] *Insurance Asset Management*, 24 January 2024.
[471] https://www.ipe.com/news/rexam-pension-plan-in-14bn-buy-in-deal-with-rothesay/10071256.article
[472] https://www.ipe.com/news/uk-innovation-and-tech-pension-scheme-in-400m-buy-in-deal-with-just-group/10071337.article
[473] *Insurance Asset Management*, 5 February 2024.
[474] *Insurance Asset Management*, 14 February 2024.
[475] https://realassets.ipe.com/news/just-group-invests-in-uk-long-income-healthcare-assets-via-alphareal/10071606.article
[476] *Insurance Asset Management*, 16 February 2024.
[477] https://realassets.ipe.com/news/pic-invests-further-30m-in-northern-ireland-social-housing/10071660.article
[478] *Insurance Asset Management*, 21 February 2024.
[479] *Insurance Asset Management*, 4 March 2024.
[480] *Insurance Asset Management*, 7 March 2024.

- In March, the Transport for London Pension Fund purchased the 26MW Wadlow offshore wind farm from a DIF Capital Partners-managed infrastructure fund.[481]
- In March, the Ockham Pension Scheme completed a £110m buy-in with Just Group.[482]
- In March, the Debenhams Retirement Scheme completed a £600m bulk transfer to Clara-Pensions, exiting the Pensions Protection Fund and restoring full benefits for its 10,000 members.[483]
- In March, M&G agreed a £309m bulk purchase annuity deal with an unspecified counterparty.[484]
- In March, the Next Group Pension Plan completed a full scheme buy-in with PIC for £510m, covering 3,600 pensioners and deferred members.[485]
- In March, the Standard Group UK Pension Scheme agreed a £26m buy-out with Just Group.[486]
- In March, Lucite International UK Pension Fund, a subsidiary of Mitsubishi Chemical UK, completed a £130m buy-in deal with Just Group, covering156 pensioners and 282 deferred members.[487]
- In March, the Menzies Pension Fund agreed a £260m buy-in with Just Group, covering 3,000 members.[488]
- In April, De Beers UK Pension Scheme completed a £850m full buy-in deal with PIC, covering 464 pensioners and 473 deferred members.[489]
- In April, the Energizer UK Pension Plan agreed a £44m full buy-in with Just Group, covering 409 pensioners and 358 deferred members.[490]
- In April, the Riverstone Management pension scheme agreed a £95m full buy-in with Standard Life, covering 388 members.[491]
- In April, the Epson (UK) Limited Pension Scheme executed a £60m buy-in with Just Group, covering 113 pensioners and 289 deferred members.[492]

[481] https://realassets.ipe.com/news/transport-for-london-pension-buys-26mw-offshore-uk-wind-farm-from-dif/10072159.article
[482] https://www.ipe.com/news/ockham-pension-scheme-completes-110m-buy-in-deal-with-just-group/10072192.article
[483] The Debenhams scheme had been in PPF assessment since 2019, when Debenhams became insolvent; https://www.ipe.com/news/clara-pensions-completes-second-transaction-with-debenhams/10072214.article
[484] *Insurance Asset Management*, 21 March 2024.
[485] https://www.ipe.com/news/next-group-completes-510m-buy-in-deal-with-pension-insurance-corporation/10072419.article
[486] *Insurance Asset Management*, 28 March 2024.
[487] https://www.ipe.com/news/lucite-international-pension-fund-in-130m-buy-in-with-just-group/10072662.article?
[488] *Insurance Asset Management*, 2 July 2024.
[489] https://www.ipe.com/news/de-beers-pension-scheme-completes-850m-full-buy-in-deal-with-pic/10072506.article
[490] *Insurance Asset Management*, 3 April 2024.
[491] *Insurance Asset Management*, 3 April 2024.
[492] *Insurance Asset Management*, 8 April 2024.

- In April, the Epson Telford Limited Pension and Life Assurance Scheme completed a £50m full scheme buy-in with PIC, covering 368 pensioners and 493 deferred members.[493]
- In April, the Lexmark Pension Plan agreed a £46m buy-in with Canada Life, covering 93 pensioners and 84 deferred members.[494]
- In April, L&G completed a £16m buy-in with the John Graham (Dromore) Limited Pension and Life Assurance Scheme, covering the benefits of 172 retirees and deferred members.[495]
- In May, the Rathbones pension scheme agreed a £100m buy-in with Canada Life, covering 480 members.[496]
- In May, the Norgine Limited Retirement Benefits Scheme completed a full buy-in transaction for £28m with Canada Life.[497]
- In May, the ICI Pension Fund executed a £900m buy-in with L&G, covering 7,000 retirees.[498]
- In May, the Telereal Pension Plan completed a £130m full scheme buy-in with Aviva, covering 500 members.[499]
- In May, L&G completed the third and final buyout with Nortel Networks UK Pension Plan.[500]
- In May, the Arqiva Defined Benefit Pension Plan executed a £204m full scheme buy-in with PIC.[501]
- In June, the Medical Protection Society Pension Scheme completed a £125m full scheme buy-in with Rothesay, covering 618 scheme members.[502]
- In June, the Sibelco UK Occupational Pension Scheme has agreed a £165m full buy-in with Aviva, covering all 1,200 members.[503]
- In June, the Rolls-Royce & Bentley Pension fund completed a £880m full scheme buy-in with Standard Life, covering 6,000 members. Standard Life also concluded a £300m deal with Unisys and a £114m deal with Vector Pension Scheme.[504]
- In June, the Contship Containerlines Limited 1979 Pension Scheme completed a £25m full scheme buy-in with L&G, covering 150 members.[505]
- In June, the Merseyside Pension Fund completed a £200m buy-in with Aviva, covering 2,500 scheme members.[506]

---

[493] *Insurance Asset Management*, 16 April 2024.
[494] *Insurance Asset Management*, 24 April 2024.
[495] *Insurance Asset Management*, 29 April 2024.
[496] *Insurance Asset Management*, 10 May 2024.
[497] *Insurance Asset Management*, 14 May 2024.
[498] *Insurance Asset Management*, 22 May 2024.
[499] https://www.ipe.com/news/telereal-pension-plan-completes-130m-buy-in-with-aviva/10073487.article
[500] *Insurance Asset Management*, 28 May 2024.
[501] *Insurance Asset Management*, 29 May 2024.
[502] *Insurance Asset Management*, 11 June 2024.
[503] https://www.ipe.com/news/sibelco-pension-scheme-completes-165m-buy-in-with-aviva/10074059.article
[504] https://www.ipe.com/news/rolls-royce-and-bentley-pension-fund-inks-880m-buy-in/10074219.article
[505] *Insurance Asset Management*, 24 June 2024.
[506] https://www.ipe.com/news/merseyside-pension-fund-in-200m-buy-in-with-aviva/10075651.article

- In July, the Taunton School pension scheme completed a full buy-in with Aviva for an undisclosed amount.[507]
- In July, M&G completed a £309m buy-in with the NSK's UK pension scheme, covering 3,700 members.[508]
- In July, the TotalEnergies UK Pension Plan agreed a £1.2bn buy-in with PIC, covering 2,000 pensioners and 3,500 deferred members.[509]
- In July, the Leprosy Mission Central Pension Scheme executed a £21m buy-in with L&G, covering 197 retirees and 88 deferred members.[510]
- In July, the Institution of Civil Engineers Staff Retirement Benefits & Life Assurance Scheme completed a £35m full scheme buy-in with Aviva.[511]
- In July, the Haberdashers Company Pension Scheme agreed a £3m buy-in with Just Group.[512]
- In July, Standard Life executed a 100m buy-in with two travel catering pension schemes.[513]
- In July, Greggs pension scheme executed a £100m buy-in with Aviva.[514]
- In July, the Moog Retirement Benefits Plan completed a £25m buy-in with Just Group, covering the scheme's remaining 28 deferred members and 139 current pensioner members.[515]
- In August, L&G agreed a £1.1bn buy-in with the SCA UK Pension Plan, covering 5,900 retirees and 3,600 deferred members.[516]
- In August, the BPT Retirement Benefits Scheme executed a £20m full scheme buy-in with Aviva, covering 49 deferred members and 50 pensioners.[517]
- In August, the Rawle Gammon & Baker Ltd Pension & Assurance Scheme completed a £23m full buy-in with Just Group, covering 113 deferred members and 154 pensioners.[518]
- In August, Railpen, the rail transport pension scheme, announced it had partnered with GreenPower to co-develop the 66MW Barachander onshore wind farm in North Argyll, Scotland; they already run the 46MW Carraig Gheal wind farm. Railpen aims to provide long-term returns for its members, while having 'a positive impact on the world in which they live'.[519]
- In August, the UK Universities Superannuation Scheme (USS) acquired a £405m portfolio of over 3,000 shared-ownership homes across the UK from a Blackstone

[507] *Insurance Asset Management*, 1 July 2024.
[508] *Insurance Asset Management*, 2 July 2024.
[509] *Insurance Asset Management*, 3 July 2024.
[510] *Insurance Asset Management*, 3 July 2024.
[511] *Insurance Asset Management*, 10 July 2024.
[512] *Insurance Asset Management*, 16 July 2024.
[513] *Insurance Asset Management*, 25 July 2024.
[514] *Insurance Asset Management*, 30 July 2024.
[515] *Insurance Asset Management*, 31 July 2024.
[516] *Insurance Asset Management*, 1 August 2024.
[517] *Insurance Asset Management*, 7 August 2024.
[518] *Insurance Asset Management*, 8 August 2024.
[519] https://realassets.ipe.com/news/railpen-and-greenpower-to-develop-66mw-scottish-onshore-wind-project/10075149.article

and Regis Group partnership. The deal is the largest shared-ownership portfolio acquisition since 1990, marking a major investment by a UK institutional investor. This investment allows USS to use its long-term capital to support …the UK social-housing sector.[520]

- In August, the Macmillan Cancer Support Pension Scheme executed a £33.7m buy-in with Aviva, covering all members.[521]
- In August, the Scottish Milk Limited Retirement Benefits Plan has agreed a £42m buy-in with Just Group, covering all 452 members.[522]
- In September, the Coats Pension Scheme completed a £1.3bn buy-in with PIC, covering and 80% of the scheme's liabilities (and 18,042 scheme members), having executed a £350m buy-in with Aviva in 2022, covering 20% of the liabilities.[523]
- In September, the Charities Aid Foundation Pension Scheme agreed £12m buy-in with Just Group, covering 64 pensioners and 155 deferred members.[524]
- In October, the Retreat York Pension Scheme agreed a £30m full scheme buy-in with Royal London, covering 202 pensioners and 108 deferred members.[525]
- In October, the Thomas Miller Retirement Benefits Scheme completed a £140m full-scheme buy-in with Aviva.[526]
- In October, the Church of England Pensions Board completed a final £145m buy-in with Aviva for the Church Workers Pension Fund (having previously completed buy-ins with Prudential in 2013 and Aviva in 2022).[527]
- In October, the Michelin Pension and Life Assurance Plan agreed a £1.5bn full-scheme buy-in with Aviva, covering 15,000 scheme members.[528]
- In October, the Rotork Pension and Life Assurance Scheme executed a £70m buy-in transaction with Aviva, covering the pension benefits for 19 current pensioners and dependants and 322 deferred members.[529]
- In October, the RAC (2003) Pension Scheme completed a £1.3bn buy-in with Aviva, covering all the scheme's 19,000 members.[530]
- In October, Deutsche Bank and L&G agreed a £1.1bn full buy-in deal, covering 4,000 scheme members, following a £570m deal in 2021 and a £500m deal in 2023.[531]

---

[520] https://realassets.ipe.com/news/uss-buys-405m-uk-residential-assets-from-blackstone-and-regis/10075174.article
[521] *Insurance Asset Management*, 19 August 2024.
[522] *Insurance Asset Management*, 27 August 2024.
[523] https://www.ipe.com/news/coats-group-scheme-completes-13bn-buy-in-deal-with-pic/10075452.article
[524] *Insurance Asset Management*, 10 September 2024.
[525] *Insurance Asset Management*, 2 October 2024.
[526] https://www.ipe.com/news/thomas-miller-and-co-complete-140m-buy-in-with-aviva/10076013.article
[527] https://www.ipe.com/news/church-of-england-pensions-board-completes-145m-buy-in-with-aviva/10076154.article
[528] https://www.ipe.com/news/michelin-pension-scheme-completes-15bn-buy-in-with-aviva/10076118.article
[529] *Insurance Asset Management*, 22 October 2024.
[530] *Insurance Asset Management*, 28 October 2024.
[531] https://www.professionalpensions.com/news/4374176/deutsche-bank-agree-gbp-1bn-deal

- In October, the St Modwen Pension Scheme completed £18m full-scheme buy-in with Just Group.[532]
- In October, the Armfield Limited Pension and Life Assurance Scheme agreed a £7m buy-in with Just Group, covering 24 pensioners and 15 deferred members.[533]
- In October, the National Grid Electricity Group of the Electricity Supply Pension Scheme completed a £1.7 billion buy-in with Aviva, covering 5,800 pensioners.[534]
- In November, PIC, Muse and Homes England (the government's housing and regeneration agency) formed a £54m joint venture development vehicle to build 3,000 low-carbon, low-energy affordable homes for rent.[535]
- In November, the West Bromwich Building Society Staff Retirement Scheme completed a £70m buy-in with Canada Life, covering 490 deferred members and 400 pensioner members.[536]
- In November, the Atradius UK Pension Scheme agreed a £190m buy-in with PIC, covering 361 current pensioners and dependants, 344 deferred members and 66 active members.[537]
- In November, the Halma group pension schemes executed £250m buy-ins with Standard Life, covering 2,200 members.[538]
- In November, the Natwest Group agreed a £11bn buy-in with Rothesay.[539]
- In November, an unnamed pension scheme in the mechanical and electrical industry completed a £2m full buy-in with L&G, covering 16 pensioners and 3 deferred members.[540]
- In November, an unnamed pension scheme agreed a £20m buy-in with Utmost Life and Pensions.[541]
- In November, the G4S Pension Scheme executed a £1.8bn full buy-in deal with Just Group, covering 22,500 members.[542]
- In November, the Walkers Shortbread Limited Retirement Benefits Scheme completed a £34m buy-in with L&G, covering 161 retirees and 238 deferred members.[543]
- In November, the New Crown Motor Sales Limited Staff Pension Scheme agreed a £2.2m buy-in with Just Group, covering benefits of 36 members.[544]

---

[532] *Insurance Asset Management*, 29 October 2024.
[533] *Insurance Asset Management*, 31 October 2024.
[534] https://www.pensionpolicyinternational.com/uk-aviva-completes-a-1-7-billion-buy-in-with-the-national-grid-electricity-group-of-the-electricity-supply-pension-scheme/
[535] https://realassets.ipe.com/news/pic-muse-form-joint-venture-with-homes-england-to-provide-affordable-housing/10076620.article
[536] *Insurance Asset Management*, 6 November 2024.
[537] *Insurance Asset Management*, 7 November 2024.
[538] *Insurance Asset Management*, 7 November 2024.
[539] *Insurance Asset Management*, 7 November 2024.
[540] *Insurance Asset Management*, 11 November 2024.
[541] *Insurance Asset Management*, 13 November 2024.
[542] https://www.ipe.com/news/g4s-pension-scheme-completes-18bn-buy-in-deal-with-just-group/10076831.article
[543] *Insurance Asset Management*, 13 November 2024.
[544] *Insurance Asset Management*, 21 November 2024.

- In November, the Wednesbury Pension Scheme completed a £43m buy-in with Just Group.[545]
- In November, the Mitchells & Butlers Executive Pension Plan agreed a full scheme buyout with L&G.[546]
- In November, the MGN (Mirror Group Newspapers) Pension Scheme completed a £150m buy-in with Just Group, covering 1,300 in-payment scheme members.[547]
- In December, the KION Group executed a £250m full scheme buy-in transaction with Canada Life, covering around 3,000 members.[548]
- In December, the Merchant Navy Ratings Pension Fund (MNRPF) agreed a £450m longevity swap of pensioner and dependant liabilities with Metropolitan Life Insurance Company (MetLife). The transaction is structured as an insurance contract with a captive insurer in Guernsey (managed by WTW Guernsey) and onwards reinsurance to MetLife.[549]
- In December, the Avimo Pension Scheme completed a £50m buy-in with Rothesay, covering all 611 scheme members, including 416 pensioners and dependants and 195 deferred members.[550]
- In December, the Hays Pension Scheme agreed a £370m buy-in with PIC, covering 853 pensioners and dependants and 3,368 deferred members. In 2018, the scheme bought a bulk annuity policy from Canada Life for a premium of £270.6m.[551]
- In December, the Clara-Pensions superfund took over the Wates Group DB pension fund with 1,500 members, with an additional £19m of funding from Wates. The members will be transferred to an insurer via a buyout within 5-10 years. It is the first superfund transaction to be completed by an active and non-distressed business.[552]
- In December, the Tennants Consolidated Limited Pension Scheme completed a £102m full scheme buy-in with Royal London, covering 463 pensioners and 241 deferred members.[553]
- In December, the Hunt Brothers and Company Limited Pension Fund agreed a £1.4m full scheme buy-in with Just Group, covering the benefits of 8 pensioner members.[554]
- In December, the G R Wright & Sons pension scheme completed a £4m full scheme buy-in with Just Group, covering the benefits of all 13 members.[555]
- In December, the (British) Airways Pension Scheme completed a £340m longevity swap with Metlife and Zurich Assurance. The swap was structured as an insurance

[545] *Insurance Asset Management*, 26 November 2024.
[546] *Insurance Asset Management*, 27 November 2024.
[547] https://www.ipe.com/news/mgn-pension-fund-completes-150m-buy-in-with-just-group/10131042.article
[548] https://www.ipe.com/news/kion-group-completes-250m-buy-in-deal-with-canada-life/10126690.article
[549] https://www.ipe.com/news/merchant-navy-ratings-pension-fund-completes-450m-longevity-swap/10126694.article
[550] *Insurance Asset Management*, 4 December 2024.
[551] https://www.ipe.com/news/hays-pension-scheme-completes-370m-buy-in-with-pic/10127699.article
[552] https://www.ipe.com/news/clara-superfund-takes-over-wates-groups-1500-members/10127761.article
[553] *Insurance Asset Management*, 16 December 2024.
[554] *Insurance Asset Management*, 16 December 2024.
[555] *Insurance Asset Management*, 18 December 2024.

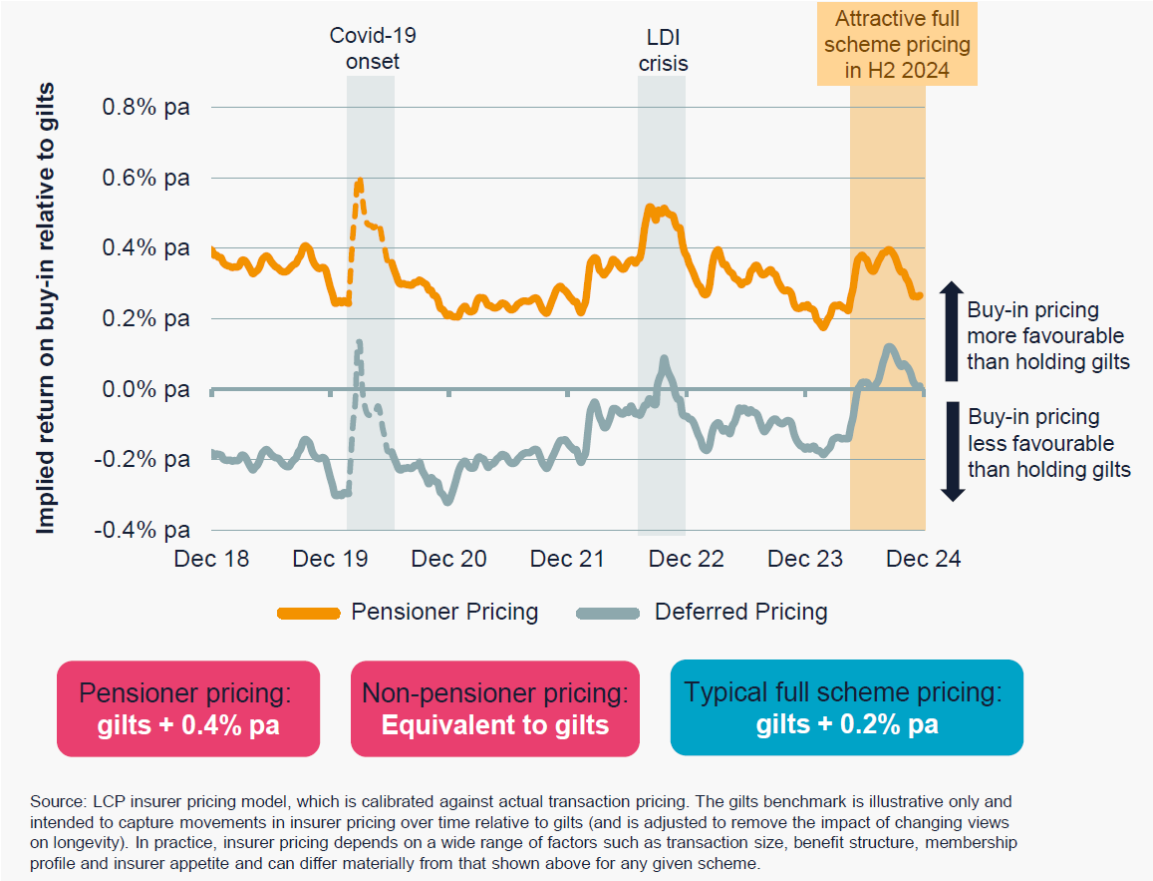
arrangement between the scheme trustees and Zurich UK, and a back-to-back reinsurance arrangement between Zurich UK and MetLife using Zurich UK's pass-through solution. MetLife assumed 100% of the longevity risk associated with around 1,100 members of the scheme.[556]

- In December, PIC executed its first buy-in transaction using Mosaic, its streamlined service for small pension schemes. It was a £20m deal with the General Council of the Bar (GCB) Pension and Life Assurance Fund and covered the pensions of 103 members.[557]
- In December, Chesnara acquired a closed portfolio of unit linked bonds and legacy pension business with approximately 17,000 policies and £1.5bn in total assets under management from Canada Life UK.[558]
- In December, the Finning Pension Scheme agreed a £250m bulk purchase annuity buy-in with Standard Life, covering all 2,170 scheme members.[559]
- In December, the ELG Haniel Metals Limited Pension and Assurance Scheme completed a £28m buy-in with Just Group, covering 99 deferred members and 81 pensioners.[560]
- K3 Advisory, in partnership with Cartwright, reported the completion of five small scheme buy-ins, all insured by Just Group.[561]

Figure 1 shows that in December 2024, pensioner pricing was based on a 'gilts + 0.40%' discount rate to value liabilities; this is less than the best peak pricing rate of 'gilts + 0.50%' at the end of 2022, and reflects the hardening of prices as insurer capacity bites. Similarly, the pricing of deferred pensioner liabilities was based on a 'gilts', down from 'gilts – 0.15%' at the end of 2022. Both were also slightly more expensive than at the end of 2019.

[556] https://www.ipe.com/news/airways-pension-scheme-completes-340m-longevity-swap/10127891.article
[557] https://www.ipe.com/news/pic-completes-first-transaction-under-streamlined-service-mosaic/10127936.article
[558] *Insurance Asset Management*, 23 December 2024.
[559] *Insurance Asset Management*, 12 February 2025.
[560] *Insurance Asset Management*, 24 April 2025.
[561] *Insurance Asset Management*, 5 February 2025.

**Figure 1: Bulk annuity pricing December 2018-December 2024 – average pricing relative to gilt yields for pensioners and deferred members**




Source: LCP's predictions for the pension risk transfer market in 2025, January 2025; https://insights.lcp.com/rs/032-PAO-331/images/LCP-predictions-for-the-PRT-market-Janurary-2025.pdf

In the US, there were 21 PRT insurers at the end of December. The regulatory burden on US life insurers has been described as 'arguably less onerous' than that facing UK life insurers which has enabled the former to invest more heavily in private assets, such as private and structured credit and private equity, via asset management firms, such as Apollo (which merged with insurer Athene), Blackstone and KKR.[562] The number of bulk purchase annuity buy-ins is low in the US compared with buy-outs. This is due to the ERISA requirement for US plan sponsors to select the 'safest available annuity provider' when transferring liabilities which is generally best met using a full scheme buy-out. In 2024, just 10 buy-in contracts were sold and total buy-in premiums were $3.7bn, only 7% of the $52bn of aggregate PRT premiums.[563]

[562] https://liferisk.news/how-many-more-asset-managers-can-the-us-pension-risk-transfer-market-absorb/
[563] https://lminvestor.com/are-bulk-purchase-annuity-buy-ins-set-to-feature-more-often-in-the-us-pension-risk-transfer-market/

According to the Milliman Pension Buyout Index, 'retiree buyout costs open 2024 at their lowest level in almost six months–despite another sizable drop in accounting discount rates'.[564] As of 31 July, the PRT cost was 102.5% of a typical plan's accounting liabilities (ABO), while, the average annuity purchase cost across all insurers was 104.9%, implying that the competitive bidding process amongst PTR providers saved plan sponsors 2.4% of PRT costs.[565] The aggregate funded status of US corporate pension funds was at 100% at the end of 2024, the first time since before the Global Financial Crisis that pension funds closed the year fully funded or better.[566] The full year PRT market volume was $49.81bn (with 800 transactions[567]), the second largest on record behind the $51.8bn executed in 2022.[568] George Palms, President at Legal & General Retirement America (LGRA) said: 'In the US, there are more than $3trn in DB pension liabilities and only about 10% of that has been de-risked so far. The steady march up in terms of taking liabilities off the balance sheet will continue due to secular trends around se-risking and string funding levels'.[569]

Erik Pickett, Actuary at Club Vita, commented: 'We've noticed a growing sophistication in mortality modelling in the US PRT market, with the majority of insurers using multi-factor models in their baseline assumptions to capture the predictive power of factors such as ZIP+4, collar type, benefit amount and gender. Insurers are now commonly using multiple factors simultaneously to capture differences in mortality rates at the individual member level, and those not using such models run the risk of adverse selection. We've also seen a growing focus on mortality improvements as insurers face the uncertainty of the long-term impact of the Covid-19 pandemic. This is the area of greatest divergence in mortality assumption setting, although there does seem to be an increasing consensus to reflect higher expected mortality improvements in the DB pensioner population over the general population. With a greater dependency on data to set mortality assumptions, the value of complete clean data from pension plans looking to transact is high. When this is unavailable, it is common for insurers to add extra margin to deals to cover the uncertainty introduced'.[570]

In March, four former AT&T pension scheme members filed a claim in the US District Court for the District of Massachusetts alleging that the 2023 PRT with Athene placed its former retirees in danger and that AT&T gained approximately $363m from the transfer, since it will save $9.6m annually in flat-rate PBGC premiums. AT&T has placed 'its retirees' futures in the hands of a risky new insurance company that is dependent on its Bermuda-based subsidiary and which has an asset base far riskier than AT&T. …[One-fifth of Athene's portfolio is invested in] risky asset-backed securities and leveraged loans

[564] https://www.pensionpolicyinternational.com/milliman-analysis-competitive-pension-risk-transfer-costs-decrease-from-101-8-to-100-5-in-december/
[565] https://www.pensionpolicyinternational.com/milliman-analysis-competitive-pension-risk-transfer-costs-climb-from-100-3-to-102-5-in-july/
[566] https://www.ai-cio.com/news/u-s-corporate-pension-funds-ended-2024-strong
[567] https://www.pionline.com/pension-risk-transfer/pension-risk-transfer-volume-hits-record-14-billion-through-q3-2024-according
[568] https://www.pionline.com/pension-risk-transfer/us-pension-risk-transfer-volume-tops-50-billion-2024-just-short-2022-record?utm_source=PIDailyWrap&utm_medium=email&utm_campaign=20250317
[569] https://liferisk.news/us-pension-risk-transfer-market-to-continue-bull-run-in-2025-and-beyond/
[570] https://liferisk.news/us-pension-risk-transfer-market-to-continue-bull-run-in-2025-and-beyond/

made to companies highly in debt. …[Further], approximately 80% of Athene's PRT liabilities are reinsured through Bermuda affiliates owned by Athene's parent, Apollo', according to the claim. AT&T was therefore in breach of its fiduciary duties under the Employee Retirement Income Security Act (ERISA). The claimants wanted AT&T to guarantee the retirement benefits that were part of workers' employment bargain with AT&T.[571] AT&T's defence was that the decision to purchase an annuity was a 'settlor decision' that is 'unassailable under ERISA's fiduciary requirements, [and hence] was not a fiduciary decision, and thus AT&T couldn't have breached any ERISA fiduciary duties in making that decision'. Further, 'While plaintiffs allege that Athene might default on its obligations at some unknown point in the future if it does a poor job of managing its assets, this allegation is far too speculative to give rise to Article III standing. To establish a case or controversy under Article III, Plaintiffs must allege an imminent threat of harm, and none of plaintiffs' allegations, either individually or in the aggregate, comes close to meeting that requirement'.[572]

Also in March, a similar claim was filed in the US District Court for the District of Maryland by former Lockheed Martin pension scheme members against the decision to transfer pension obligations to Athene: 'Instead of selecting the safest possible annuity to ensure that their employees and retirees would have continued financial security of Lockheed employees and retirees, Lockheed Martin selected Athene, which is substantially riskier than numerous traditional annuity providers'. In both cases, the plaintiffs were appealing to Interpretive Bulletin IB 95-1 (IB95-1), issued by the Department of Labor in 1995 (following the collapse of Executive Life) which specifies the fiduciary standards required to select an annuity provider for a PRT. These include considerations of the provider's investment portfolio, size relative to the annuity contract, level of capital and surplus, liability exposure and availability of state government guaranty associations. In short, IB95-1 requires the purchase of the 'safest annuity available'.

Under the SECURE 2.0 Act of 2022, the DOL was mandated to review Interpretive Bulletin 95-1 on pension risk transfers and recommend possible modifications to Congress.[573] In May 2024, the Employee Benefits Security Administration (part of the DOL) said it was preparing a report for Congress and was considering changes to the guidance in IB 95-1 concerning standards for employers in selecting third-party insurers to convert plan funds into annuity contracts. The current guidance requires plans to consider the 'safest available annuity' in choosing an insurer for PRTs. Ada Dolph, partner at Seyfarth Shaw LLP, pointed out that 'With the lawsuits that have been happening, there's been increased focus on private equity getting into this area of risk transfers, and a lot of concern that private equity is supported by investments that may be at some level riskier than a traditional insurance company'. Dolph also said that EBSA might require that fiduciaries consider an insurance company's ownership, control, and ability to administer

[571] https://www.ai-cio.com/news/att-sued-over-2023-pension-annuitization-with-athene. A second lawsuit was filed a few days later, see: https://www.pensionpolicyinternational.com/us-att-faces-second-lawsuit-over-pension-plan-risk-transfer/

[572] https://www.pensionpolicyinternational.com/att-seeks-dismissal-from-two-lawsuits-targeting-prt-deal-with-athene/

[573] https://www.pensionpolicyinternational.com/us-pension-risk-transfers-trigger-new-erisa-litigation/

payment of benefits, as well as providing a model statement that fiduciaries can show to participants explaining the risk transfer.[574] The report was released in June 2024, but it did not recommend any specific changes to IB 95-1 at that time, instead concluding that: 'Further exploration into developments in both the life insurance industry and in pension risk transfer practices is necessary to determine whether some of the Interpretive Bulletin's factors need revision or supplementation and whether additional guidance should be developed'.[575]

In August, the US National Association of Insurance Commissioners (NAIC) discussed the issue of funded reinsurance. Like the PRA, the NAIC, while recognizing the role of reinsurance in managing risk and capital, was concerned about the concentration of risks in a small number of offshore counterparties often based in Bermuda, correlations in risk due to the dependence of many reinsurers' business models on credit, and the risk associated with illiquid assets, especially in scenarios when it is necessary to recapture reinsured liabilities. The NAIC considered proposals put forward by the Life Actuarial Task Force (LATF) which would require asset adequacy testing using cash flow methodologies for ceded reinsurance transactions. The International Association of Insurance Supervisors (IAIS) was also monitoring the growth of cross-border reinsurance, according to a report by Hogan Lovells.[576]

In October, Oliver Wyman and Mercer (both subsidiaries of Marsh McLennan) introduced a new pension risk transfer longevity model that will enable pension plan sponsors, direct insurers and reinsurers to better price and manage longevity risk. The model is based on Mercer's US longevity dataset of over one million pension lives, which incorporates socioeconomic and demographic factors. It has been designed to allow users to extract tailored insights and analytics. These will assist in enhancing the prediction, understanding, and effective management of longevity risk within a PRT transaction: 'Having a more comprehensive understanding of their plan's longevity risk will make these transfers more attractive to insurers'.[577]

Highlights for 2024 in the US included:

- In February, Prudential Financial completed a pension risk transfer deal with Shell USA for $4.9bn, covering around 21,500 of the company's US retirees.[578]
- In March, Prudential Financial and RGA were selected to execute a PRT with Verizon Communications valued at $5.9bn covering 56,000 pensioners.[579]

[574] https://www.pensionpolicyinternational.com/us-pending-dol-report-to-consider-pension-risk-transfer-changes/
[575] https://www.ai-cio.com/news/no-recommendations-yet-from-the-labor-department-on-prt
[576] https://www.pensionpolicyinternational.com/regulators-increase-scrutiny-on-funded-reinsurance-amid-pension-de-risking-surge/
[577] https://www.pensionpolicyinternational.com/new-pension-longevity-model-launched-by-oliver-wyman-and-mercer/; https://www.oliverwyman.com/media-center/2024/oct/oliver-wyman-and-mercer-launch-new-pension-risk-transfer-longevity-model.html
[578] *Insurance Asset Management*, 8 February 2024.
[579] *Insurance Asset Management*, 7 March 2024.

However, in December, the pensioners filed a lawsuit against Verizon management and State Street Global Advisors for allegedly breaching fiduciary duties under ERISA, claiming that the company chose the 'cheapest' rather than the 'safest' annuity provider, exposing them to undue risk. Verizon denied the claims and pledged a strong defense.[580] In January 2026, a US District Court judge dismissed the case, ruling that the plaintiffs failed to demonstrate 'a substantial risk' of not receiving full pension benefits or any 'present injury'.[581]

- In March, IT technology company Unisys closed an agreement with F&G Annuities & Life to purchase $200 million in group annuity contracts. Since 2021, Unisys has offloaded around $2 billion in pension liabilities, including those from subsidiaries' pension plans in the Netherlands and Switzerland.[582]
- In June, 3M transferred $2.5bn in pension liabilities, covering 23,000 retirees, to Metropolitan Tower Life, a subsidiary of MetLife.[583]
- In August, PICA completed the first PRT involving a multiemployer pension plan. The $221m deal with Sound Retirement Trust, based in Seattle, covers 8,700 retirees and beneficiaries.[584]
- In September, PICA agreed a second PRT deal (for $6bn) with International Business Machines Corporation (IBM), covering 32,000 retirees.[585]
- In December, MetLife and General Atlantic established Chariot Re, a Class E Bermuda-based life and annuity reinsurance company.[586]

In February, Ford of Canada's pension plan agreed a C$923m group annuity buy-out for 2,700 plan members with RBC Insurance, Sun Life and Desjardins Group. In March, RGA Life Reinsurance Company of Canada (RGA Canada) completed a C$5.8bn life reinsurance transaction with Manulife, the largest universal life reinsurance transaction in Canada to date.[587] In October, IBM Canada concluded a C$1.5bn buy-out for 6,000 plan members with Blumont Annuity and RBC Insurance. The Canadian PRT market reached a new peak in 2024 with 130 transactions worth C$11bn. An unusual feature of the Canadian market, in comparison with the US and UK markets (with 20 and 11 insurers, respectively), is that often more than one insurer is involved in the transaction, although there is one lead insurer and the other insurers are doing a buy-in of the main insurer. The market is highly concentrated with six insurers – Sun Life, Blumont Annuity, AI Financial Group, BMO insurance, RBC Insurance and Desjardins Group – accounting for 99% of the market. They are well capitalized under Canada's Life Insurance Capital Adequacy Test (LICAT). The 2023 Pension Protection Act gave super-priority status for pension deficits in the event of corporate insolvency and this led to an increased demand for annuity

[580] pionline, 3 January 2025.
[581] pionline, 13 January 2026.
[582] https://www.pensionpolicyinternational.com/us-unisys-announces-200m-pension-risk-transfer/
[583] https://www.ai-cio.com/news/3m-to-transfer-2-5b-in-pension-liabilities-to-met-tower-life
[584] https://www.pensionpolicyinternational.com/us-prudential-to-complete-industrys-1st-multiemployer-pension-risk-transfer/
[585] https://www.pensionpolicyinternational.com/ibm-completes-6-billion-pension-buyout-with-prudential-its-second-in-2-years/
[586] *Insurance Asset Management*, 12 December 2024
[587] *Insurance Asset Management*, 25 March 2024.

purchases to hedge pension-related risks. By the end of 2014, only 15% of the Canadian pensions had de-risked.[588]

The Dutch market PRT market was relatively quiet in 2022-23 with only around €100m of transfers from pension funds to insurers, e.g., NN bought out the accrued pension liabilities of Metro. The plan for a national switch from a DB to a DC pension system, which passed into law in July 2023, has been put on hold due to the absence of an agreed government following the November 2023 general election – one of the parties, the Freedom Party (PVV), promised to reverse the switch. If the switch does go ahead, this could lead to transfers from the small number (around 44) of company-sponsored schemes that intend to liquidate their existing scheme rather than transition members to DC in line with the new law. This could result in around €25bn being transferred to insurers.[589] At the start of 2024, there were four buy-out insurers: NN, Zwitserleven (bought by Bermuda-based Athora Holdings in 2020), ASR and Lifetri. In May, Lifetri pulled out of the market, having secured only one pension fund buy-out in the previous four years (with the Dutch pension fund of Allianz in 2020), selling its business to Dutch insurer Achmea. In November, NN concluded a €45m buy-out with the pension fund of Calpam and Zwitserleven concluded a €650m buy-out with the pension fund of Yara.[590] In December, ASR completed a €1.6bn buy-out of the closed professional scheme for dentists.[591] Despite strong funding ratios, many companies prefer to transition to DC on their own or join a pooled pension fund (APF), both of which allow funds to continue investing in risk assets which can be used to compensate members who are disadvantaged by the move to DC.[592] In December, Dutch insurer Achmea and US investment firm Sixth Street Partners announced a joint (80:20) venture to enter the Dutch pension buy-out market under the name Achmea Pensioen & Leven (Pension & Life).[593]

The pension risk transfer and buyout market has been slow to develop in Germany, but this is about to change. Prior to 2002, German companies provided pensions to their employees on a 'book reserve' basis. Employees were given a 'direct promise' (Direktzusagen) and the resulting liability accrued on the corporate balance sheet and was financed from free cash flow. In 2002, International Accounting Standards (IAS) were incorporated in EU law which required companies to recognize the net present value of pension surpluses or deficits in their profit and loss account. Since then, companies have funded pension liabilities through Pensionsfonds vehicles or contractual trust arrangement (CTA) structures, while continuing to bear the risks, although some risks have been hedged with insurance solutions.

---

[588] https://liferisk.news/canadian-pension-risk-transfer-market-set-to-establish-higher-floor-as-aggregate-deal-value-surges/

[589] https://www.ipe.com/special-reports/risk-transfer-special-report-pension-liabilities-shift-to-insurers/10071342.article

[590] https://www.ipe.com/news/dutch-funds-yara-and-calpam-conclude-buyouts/10076709.article

[591] https://www.ipe.com/news/nedlloyd-fund-concludes-950m-buyout-with-zwitserleven/10129954.article

[592] https://www.ipe.com/news/why-the-dutch-buyout-market-fails-to-fulfil-its-promise/10074113.article

[593] https://www.ipe.com/news/achmea-and-sixth-street-merge-to-enter-dutch-buyout-market/10126683.article?

In February 2024, it was reported that Allianz Global Investors (AllianzGI) and Deutsche Betriebsrenten Holding (DBR) had agreed a PRT partnership. The pension liabilities of DBR were demerged in line with the German Transformation Act (Umwandlungsgesetz) and transferred to a separate company (known as a pension corporation, pensioner company or Rentnergesellschaft). The pension corporation, which will pay the pensions, was acquired by DBR, acting as the external risk carrier. This structure is based on German corporate law rather than insurance law. It gives a high degree of flexibility and more attractive price for the ceding company. In particular, it allows the option to transfer the liabilities to an external pension corporation over time, while preserving liquidity. The ultimate goal is, according to DBR's managing partner Thomas Bloch, a 'full and final release of the corporate groups from the pension obligations, economically, financially and operationally'. To achieve this, sufficient assets needed to be transferred in order to meet all future pension payments and associated expenses. The costs of the transfer were close to the company's book value of pension liabilities. AllianzGI will provide asset-liability management (ALM) and asset management expertise, insolvency protection and cash flow management via the Allianz CTA.

AllianzGI plans to offer this PRT solution to other German companies, international companies (e.g., Japanese, Finnish and French) with German subsidiaries, and companies based in other countries, such as Japan, France, the UK, US and Benelux. According to Bloch, 'pension buyouts are also highly relevant in M&A transactions. Addressing this aspect at an early stage increases the M&A readiness of companies and enables smoother and better deals'. PRT's via a Rentnergesellschaft strengthen the sponsor's equity ratio, avoiding future volatility, allowing companies to focus on the core business. Further, the transfer does not require approval by pension beneficiaries, works councils (Betriebsräte), regulatory authorities such as BaFin, or the lifeboat pensions insurer PSVaG. Bloch added: 'In Germany, pensions have to be increased according to inflation; longevity risks are not captured by accounting values, a very significant difference to the UK, and there are operational and legal risks'.[594] In December, Allianz set up a new life reinsurer in Bermuda called Sconset Re, with equity capital from institutional partners.[595]

Other German companies are considering using pension corporations as a means of transferring pension obligations to a separate company through a demerger, or all-share deals, to free themselves up from liabilities, according to Aon Wealth Solutions Germany. The assets required to fund the pension corporation are significantly lower than the contributions that would be necessary if the transfer were made to an insurance company. In 2021, pension assets in Germany totalled €690b, of which €318.8bn were direct promises, €171bn were current pensions and €147bn were vested entitlements. The buy-

[594] Luigi Serenelli (2024) AllianzGI partners with DBR to offer pension risk transfer, *IPE*, February; https://www.ipe.com/special-reports/allianzgi-partners-with-dbr-to-offer-pension-risk-transfer/10071346.article
[595] *Insurance Asset Management*, 12 December 2024

out market has been slow to develop in Germany because of caution over legal and reputational risk, and also a lack of actuarial corporate pension expertise.[596]

In December, WTW announced it would set up a pension corporation as an external risk carrier in Germany to transfer pension obligations from German corporates. WTW said that pension obligations are a burden on the balance sheets of companies that are changing their business models and need more 'flexible and agile' corporate structures. The level of funding ratios for company pension schemes is at an all-time high, making it easier to implement restructuring through pension buyout solutions. The market is worth potentially €600bn.[597]

In March, RGA announced a longevity asset-intensive reinsurance deal with Japan Post Insurance Company covering a JPY700bn in-force block of individual life annuities. RGA said 'This transaction marks a significant milestone in the Asia-Pacific longevity market as a first-of-its-kind coinsurance transaction in Japan. This is one of a number of recent asset-intensive transactions that RGA has completed demonstrating our deep expertise and strong position in the Japanese and Asia Pacific markets'.[598] In May, Pacific Life Re announced an asset-intensive reinsurance agreement with Japan's Tokio Marine & Nichido Life Insurance Company (Anshin Life). The deal covered in-force whole of life policies and will provide Anshin Life with a new method to reduce long-term interest rate risk and enhance its asset liability management capabilities.[599]

In July, Melbourne-based equity release mortgage originator, Household Capital, completed a Moody's-rated reverse mortgage securitization of its AUD263mn HHC 2024-1 RMBS (Residential Mortgage-Backed Securities) Trust. Investors included life insurers, banks, credit funds and Australian superannuation funds. The first-ever Australian transaction was Bluestone's Emerald Reverse Mortgage Series 2006-1Trust in 2006, but the market has stalled since the Global Financial Crisis.[600]

The Geneva College of Longevity Science (GCLS) was launched in 2024 as the first higher education institution dedicated solely to longevity science.[601] It introduced the GCLS Executive Master in Longevity Science which explores aging from biological, financial and societal angles. The EMSc Longevity is a distance learning master's programme with the following courses: Introduction to Longevity Science, Biomedical Foundations of Aging, Public Health and Epidemiology of Aging, Social and Psychological Dimensions of Aging, Nutrition and Longevity, Exercise Physiology and Aging, Medical Longevity

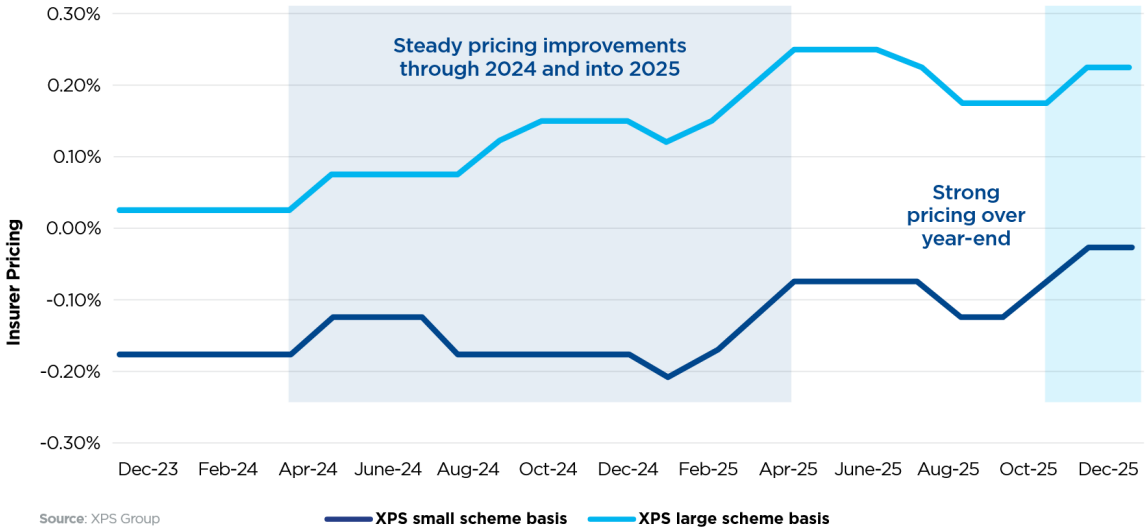
[596] https://www.ipe.com/country-reports/germanys-pension-buyout-market-shows-signs-of-life/10071861.article
[597] https://www.ipe.com/news/wtw-to-set-up-shop-in-germany-for-pension-buyout-deals/10127769.article
[598] https://www.rgare.com/our-company/media/press-releases/press-releases-detail/2024/03/22/rga-announces-700-billion-jpy-longevity-asset-intensive-reinsurance-transaction-with-japan-post-insurance-company
[599] https://www.pacificlifere.com/news/pacific-life-re-announces-new-asset-intensive-reinsurance-deal-with-tokio-marine-and-nichido-life.html
[600] https://liferisk.news/australian-equity-release-mortgage-securitisation-market-set-for-take-off/
[601] https://gcls.study/

Intervention, Longevity Supplements and Compounds, Technological Innovations In longevity, Ethics and Policy in Longevity Science and a Master Thesis.

**2025**

In 2025, there were a record-breaking 367 PRT transactions in the UK valued at £38.2bn. The key insurers involved were L&G (£10.2bn, with a 27% market share), PIC (£6.8bn, 18%), Rothesay (£5.2bn, 14%), Aviva (£4.6bn, 12%), Standard Life (£3.9bn, 10%), and Just Retirement (£3.1bn, 5.4%). Transactions for small sub-£100m schemes accounted for 85% of 2025, with all 11 insurers in the market[602] completing buy-ins in the sub-£100m segment. So while the total value of 2025 transactions was 20% below the 2024 level, the number of transactions increased by 23%, from 298 to 367. 2025 was also a record year for longevity swaps, totalling £25.9bn.[603]

**Figure 2: Bulk annuity pricing December 2023-December 2025 – average pricing relative to gilt yields for small schemes and large schemes**




Note: The pricing is based on observed market pricing and model points from bulk annuity insurers. Actual bulk annuity pricing is specific to a particular scheme's demographic and benefit profile, and other wider factors influencing appetite for a transaction. Source: XPS Bulk annuity market January 2026 trustee update; https://www.xpsgroup.com/news-views/insights-briefings/bulk-annuity-market-january-2026-update/

Figure 2 shows that over the period December 2023-December 2025, small scheme liabilities were discounted at a 0.2%-0.325% lower rate compared with large scheme liabilities. To illustrate, in December 2025, the rate was 'gilts – 0.025%' for small schemes

[602] The others were Royal London, M&G, Canada Life, Utmost and Blumont.
[603] https://www.ipe.com/analysis/landg-dominates-uk-pension-risk-transfer-market-with-27-share/10135991.article

and ‘gilts + 0.225%’ for large schemes. The XPS DB: UK – Buyout Funding Level was 113% in December 2025 compared with 98% in December 2023.[604]

Despite the choice between insurance and run-on, consultant LCP expected insurance to remain the ultimate endgame for the majority of schemes and this was driving the continued high demand for buy-ins. It also expected that the numbers of smaller scheme transactions will continue to grow as insurers increase their capacity.[605] Consultant XPS, for example, has developed XPS Catalyst as an efficient end-to-end buyout solution for schemes with assets below £15m.[606] By the end of the year, around £500bn of pension scheme liabilities across more than 2,000 schemes had been insured via PRT since 2007.[607] The Pension Protection Fund reported that at the end of December, the aggregate DB funding ratio was 129.9%, with 3,675 schemes holding almost £260bn in surpluses; there were 1,294 underfunded schemes with total deficits of £19.3bn.[608] L&G predicted that the UK PRT market would see another £500bn in transactions between 2029 and 2043, while the global PRT market was on track for a ‘transformative period’.[609]

LCP also expected that there would be an increased focus on non-pricing factors when selecting insurers:[610]

- Member service: With the majority (95%+) of transactions now full buy-ins, there is increasing focus on insurers’ administration capabilities and service levels.
- Web functionality: A majority (55%) of schemes polled at LCP’s 2024 DB pensions conference said they would not transact with an insurer unless members would receive an equivalent service after the transaction.
- Illiquid asset solutions: Whilst a range of cost-effective solutions exist for dealing with illiquid asset holdings by schemes seeking to insure, the haircuts incurred can be significant for some asset classes (e.g., 30%+). An insurer’s ability to work collaboratively with a scheme to solve its specific illiquid asset challenges can be extremely valuable as in British Steel Pension Scheme’s £7.5bn full insurance with L&G and Coats UK Pension Scheme’s £1.3bn buy-in with PIC.
- Environmental, social and governance factors: ESG considerations will take higher priority given increasing trustee focus in this area and the importance of robust management of climate-change related risks.[611]
- Insurer financial reviews: Schemes are looking to understand the differences across the market in areas such as capital resilience, asset portfolio and approach to funded

[604] https://www.xpsgroup.com/news-views/insights-briefings/bulk-annuity-market-january-2026-update
[605] https://www.europeanpensions.net/ep/Another-bumper-year-expected-for-UK-pension-risk-transfer-market.php
[606] https://www.xpsgroup.com/what-we-do/pensions-advisory/xps-catalyst/
[607] *Insurance Asset Management*, 29 January 2026.
[608] https://lminvestor.com/2025-provides-activity-change-and-evolution-for-uk-pension-risk-transfer-market/
[609] *Insurance Asset Management*, 14 August 2025.
[610] LCP’s predictions for the pension risk transfer market in 2025, January 2025
[611] This is considered in more detail below.

reinsurance when assessing insurer financial strength and risk exposure as part of insurer selection.

In January, the PRA released a report outlining how it expects bulk purchase annuity insurers in the UK to manage the increased growth and complexity in the market, including on the use of funded reinsurance (FundedRe). It expected BPA insurers to proactively manage their capacity to support growth in a 'prudent manner' and ensure that high levels of competition do not weaken firms' pricing disciple and incentivize weaker risk management standards. It noted that BPA transaction structures and complexity were evolving, with features such as long price locks, trustee termination options, and in specie premiums. These may require new risk management approaches or exposure limitations. It added that it would continue to focus on funded reinsurance in 2025, amid concerns from the Financial Policy Committee that the current growth in funded reinsurance transactions could lead to a rapid build-up of risks in the sector and has the potential to pose systemic risks. Yet, insurance firms' self-assessments were not fully meeting the PRA's supervisory expectations in this area: 'firms' current internal investment limits for aggregate exposures appear insufficient to prevent a build-up of systemic risk in view of current activity trends. Firms' single name exposure limits also do not currently appear to align with our expectation that single counterparty exposures should not threaten firms' ability to meet their solvency risk appetite upon recapture'. The PRA expected relevant firms to make rapid progress in addressing gaps identified against its expectations. In addition, a funded reinsurance recapture scenario would be included in the 2025 Life Insurance Stress Test (LIST 2025); this will help the PRA to assess and compare exposures across the market. It said it would consider the further use of its powers if firms were not implementing the risk management practices needed to mitigate the risks funded reinsurance poses. Some firms had individual counterparty FundedRe exposures that could see them falling below their solvency risk appetite in the event of a reinsurer default – although they would still meet their regulatory Solvency Capital Requirement.[612]

Also in January, the UK government announced proposed changes to pensions rules to allow surplus funds in DB schemes (valued at £160bn) to be invested in the wider economy in the form of 'productive finance' as a way of contributing to economic growth, its primary economic objective. Rachel Reeves, Chancellor of the Exchequer, said: 'We will introduce new flexibilities for well-funded defined benefit schemes to release surplus fund where it is safe to do so, generating even more investment into some of our fastest growing industries'. TPR CEO Nausicaa Delfas said: 'Many defined-benefit pension schemes are better funded than at any point in recent history – with around 80% of schemes fully funded. Our first priority must be to ensure pension-scheme members have the best chance of receiving their promised benefits. Where schemes are fully funded and there are protections in place for members, we support efforts to help trustees and employers consider how to safely release surplus if it can improve member benefits or unlock investment in the wider economy'.[613]

[612] https://www.pensionsage.com/pa/PRA-outlines-priorities-for-BPA-insurers-in-2025.php
[613] https://www.pensionpolicyinternational.com/uk-pensions-experts-react-to-governments-db-surplus-plan/

Sir Steve Webb, partner at pension consultancy LCP and a former pensions minister, said that the proposal was a very welcome development, but without guarantees from the Pension Protection Fund the impact would be limited: 'Ideally the Government would go further and offer a way of guaranteeing member benefits, such as enhanced cover by the PPF, which would allow all surplus schemes to participate in this new option'.[614] Consultant XPS predicted that DB surplus extraction 'could unlock £100bn of value over the next decade, providing substantial benefits to both members and employers, while supporting the government's growth agenda'.[615] An XPS survey of around 300 trustees, employers and pension managers found that 70% said they supported the government's intention to allow DB schemes to extract surplus.[616] However, surplus extraction was likely to slow down the transition to buy-out of the remaining DB pension schemes in the UK.

In March, Brookfield announced that Brookfield Wealth Solutions (BWS), its insurance subsidiary, would enter the UK bulk annuity pensions market with the aim of completing deals worth around $4 billion a year, a similar volume to that which it achieved in its principal US and Canadian markets in 2024.[617] It will trade under the name Blumont Annuity UK, with Thomas Olunloyo as CEO and Keli Zhang as Chief Investment Officer. Also in March, InEvo Re, a new reinsurer set up by Macquarie Asset Management, was reported to have entered into an agreement with a UK insurer to reinsure its PRT liabilities, including both pensions in payment and deferred pensioners. InEvo Re's aim is to deliver innovative capital and risk solutions to life insurers, supported by access to Macquarie Asset Management's insurance asset management capabilities, global platform, and expertise.[618]

In April, David Walmsley, director of trusteeship, administration and DB supervision at The Pensions Regulator, said that superfunds needed scale to become a viable endgame option for smaller DB schemes: 'We see DB consolidation, whether in a superfund or more conventional master trust, as a positive for ensuring good outcomes for savers in such schemes. But the superfund market needs scale to take on small schemes and we hope the upcoming Pensions Schemes Bill – which will establish a permanent legislative framework for them – will provide impetus for further innovation and expansion'. The Clara superfund has completed three deals since it was approved by the regulator in late 2023. Walmsley said that it could have closed more business. He estimates that around 40% of DB schemes met the threshold for a superfund transfer in 2024, of which, 1,400 had less than £100m of assets, with 900 at below £25m. This end of the market is beginning to be served by the DB insurance companies which have developed platform process streamlining with features such as real-time pricing. But superfunds still have much to offer, according to

[614] https://www.telegraph.co.uk/business/2025/01/28/reeves-targets-private-sector-pensions-in-push-for-growth
[615] https://www.ipe.com/news/db-surplus-extraction-could-boost-uk-economy-but-detail-will-be-key/10128702.article
[616] https://www.ipe.com/news/majority-of-trustees-support-uk-surplus-extraction-plans/10128716.article
[617] https://www.pensionpolicyinternational.com/brookfield-eyes-uks-pensions-risk-deals-with-insurance-spin-off/
[618] https://www.reinsurancene.ws/macquarie-asset-managements-inevo-re-enters-prt-agreement-with-uk-insurer/

Andrew Grime who leads Aon's superfund team. He said that schemes can rely on an estimate of buy-out pricing from an actuary with experience of the market, rather than incur the costs of seeking a quote from an insurer.[619]

In April, the Clara-Pensions superfund announced that it would set up a private markets investment vehicle, the Clara Private Markets Vehicle, in association with asset manager Van Lanschot Kempen. It will invest initially in private credit and later in other assets, such as infrastructure debt and real estate debt. Around 30-35% of assets will be held in private markets, with a 'significant proportion' in the UK, hence 'further increase[ing] our contribution to the UK economy'.[620]

In June, the UK Government introduced a Pension Schemes Bill which will:[621]

- Introduce a value for money framework for defined contribution schemes to enable a shift in focus from cost towards value and protect savers from becoming stuck in underperforming arrangements for extended periods.
- Simplify retirement choices, with all pension schemes offering default routes to an income in retirement.
- Bring together small pension pots worth £1,000 or less into one pension scheme that is certified as delivering good value to savers, making pension saving less hassle and more rewarding.
- Establish new rules creating multi-employer DC scheme 'megafunds' of at least £25 billion, so that bigger and better pension schemes can drive down costs and invest in a wider range of assets.
- Provide increased flexibility for defined benefit pension schemes to safely release surplus worth collectively £160bn, to support employers' investment plans and to benefit scheme members.
- Remove the restrictions that prevent Pension Protection Fund's board from reducing the annual pension protection levy it collects.
- Legislate for DB pension scheme superfunds to encourage growth of the superfund market and underpin the security of members' benefits.
- Consolidating and professionalising the Local Government Pension Scheme (LGPS), with assets held in six pools that can invest in local areas infrastructure, housing and clean energy.

One of the Bill's key aims is to 'drive £50bn of [productive] investment directly into the UK economy' to encourage growth in the UK economy. This may have the effect of slowing down the PRT market amongst schemes in surplus. LCP argues that the easing of the gateway tests that govern scheme entry into a superfund will allow pension funds that are underfunded on a buy-out basis to consider a superfund instead. It estimates that around half of all DB schemes, with combined assets of £600bn, could ultimately become eligible

[619] https://www.portfolio-institutional.co.uk/defined-benefit/superfunds-need-scale-to-support-smaller-schemes-tpr/
[620] https://www.ipe.com/news/clara-superfund-launches-private-markets-investment-vehicle/10129907.article
[621] https://www.professionaladviser.com/news/4414586/game-changer-pension-schemes-laid-parliament

for a superfund transfer.[622] Consultant XPS in a note to employers entitled 'Why employers should consider using superfunds to secure DB benefits' pointed out some advantages: secure benefits with capital backing without needing an insurer transaction, and cheaper than securing benefits with an insurer (typically 90-95% of the cost of insurance); but warned of some drawbacks: need to meet 'onboarding conditions', lack of choice (Clara Pensions is the only provider), and weaker security compared to securing benefits with an insurer because capital requirements are lower for superfunds.[623]

In June, the 730-member Church Mission Society Pension Scheme transferred its £55m assets to the Clara-Pensions superfund – joining CMS, retailers Sears and Debenhams, and construction company Wates.[624]

In July, Athora, the European savings and retirement services group with branches in Netherlands, Italy, Belgium and Germany, acquired the Pension Insurance Corporation for £5.7bn. At the time, Athora had €76bn of assets under management and administration and 2.8 million policyholders, while PIC had £50.9bn in assets and provided pensions to 400,000 retirees. PIC became the UK insurance business of Athora and continued to operate under the PIC brand. PIC's former shareholders included Apollo Global Management, Athene Holding Limited and the Abu Dhabi Investment Authority.[625]

In July, Legal & General entered into a long-term strategic partnership with Blackstone, the world's largest alternative asset manager. L&G's £92bn annuities business will use Blackstone's $465bn private credit origination platform to gain access to diversified investment-grade assets, primarily based in the US. The aim is to strengthen L&G's ability to write US pension risk transfer business.[626]

In July, the Society of Pension Professionals (SPP) released a report entitled *Less friction, better transfers: creating a more agile risk transfer process*[627] which called for cross-industry collaboration to standardize streamlined bulk purchase annuity processes to increase efficiency, while recognizing that a single standard template is unlikely to be achievable. A particular concern was the difference in data and information requirements between insurers, e.g., in terms of benefit definitions, and this especially impacted smaller schemes. The SPP pointed out that a streamlined process could play an important role in well-established and clearly structured broking processes, with pre-negotiated contracts,

[622] https://www.ipe.com/news/superfunds-gain-traction-in-defined-benefit-endgame-says-lcp/10131687.article
[623] XPS Express for Employers, August 2025.
[624] https://lminvestor.com/tpt-run-on-superfund-seen-widening-de-risking-options-as-rules-loosening-promises-more-alternatives/
[625] https://www.reinsurancene.ws/athora-to-acquire-pension-insurance-corporation-for-5-7bn/
[626] P&I Daily, 11 July 2025.
[627] https://the-spp.co.uk/wp-content/uploads/SPP-Risk-Transfer-Paper-July-2025-FINAL.pdf

which could give insurers additional confidence that transactions will go ahead efficiently and with minimal costs.[628]

In July, it was announced that Brookfield Wealth Solutions agreed to buy Just Group for £2.4bn. BWS said that Just and its subsidiary Blumont Annuity Company UK would operate as a single, consolidated insurance group under the Just brand. BWS was planning to 'create a leader in the UK annuity and life insurance space'. It added: 'Just will maintain its offering in individual annuities while enhancing its ability to capitalize on evolving retirement trends, including the growing opportunities in defined contribution pensions, with £1.3trn in UK defined contribution assets projected across 14.9 million active savers by 2044. The combined UK group, with the support of BWS's balance sheet and expertise in individual annuities and wealth solutions, will be able to reinvest capital strategically in these key growth areas'.[629]

In September, M&G announced plans to introduce a with-profits bulk purchase annuity in 2026.[630]

In October, TPT Retirement Solutions said it would launch a defined benefit superfund to run on pension liabilities rather than buyout, after securing capital for £1bn of transactions. TPT's superfund will be established with an independent trustee board and full-time executive team. As a run-on superfund, it could invest in growth assets which would support the government's aim to boost long-term UK investment. Transferred schemes will be eligible for surplus sharing after five years.[631]

In October, Phoenix Group announced that it was in partnership discussions with private capital firms – Blackstone, KKR and Sixth Street – to raise around £1bn to accelerate the growth of its UK PRT business. Michael Abramson, partner at Hymans Robertson, said that stable and attractive returns continue to draw international capital, adding that a lot of overseas investors had been trying to find a way into the market 'for quite a long time', with reinsurance being the most common route to date. David Honour, head of insurance consulting at XPS, noted that the lines between insurance and asset management were becoming increasingly blurred: 'Asset managers bring enhanced investment capabilities to insurers. By the combination of the asset management capabilities and the insurer operating under a regulatory regime, that creates a more optimal structure for insurers to operate under and allows them to be more competitive in the market. Further consolidation is

[628] https://www.ipe.com/news/pension-professionals-call-for-standardisation-of-bulk-purchase-annuity-processes/10131905.article
[629] https://www.professionaladviser.com/news/4517090/group-agrees-4bn-brookfield-takeover-deal
[630] *Insurance Asset Management*, 3 September 2025; https://lminvestor.com/tpt-run-on-superfund-seen-widening-de-risking-options-as-rules-loosening-promises-more-alternatives/
[631] https://www.ipe.com/news/tpt-retirement-solutions-enters-superfund-market-with-1bn-run-on-model/10133101.article; https://lminvestor.com/tpt-run-on-superfund-seen-widening-de-risking-options-as-rules-loosening-promises-more-alternatives/

likely, driven by natural synergy between insurers' long-dated liabilities and the long-term assets that asset managers can provide'.[632]

In November, the Prudential Regulation Authority reported the results of its 2025 life insurance stress test (LIST25) which covered 11 of the largest companies in the BPA market, accounting for more than 90% of annuity liabilities. The test allowed for a decline in risk-free interest rates, falls in equity and property prices, widening credit spreads and subsequent defaults and downgrades. The PRA found that all firms met their regulatory capital requirements, showing a 'robust starting position and ability to absorb significant shocks'. The test also included two exploratory scenarios to capture evolving BPA market risks, examining the industry's asset concentrations and funded reinsurance modelling capabilities. The PRA found that businesses were able 'to model these scenarios effectively'.[633]

Highlights for 2025 in the UK included:

- In January, Clarks Footwear Pension Fund completed a second buy-in with PIC for £540m, covering around 5,000 pensioners and dependants and 3,000 deferred members. The first transaction with PIC was for £280m in 2022. PIC has now insured all £820m of the fund's DB liabilities.[634]
- In January, the Compass Group Pension Plan executed a £1.5bn buy-in with Standard Life, covering 14,000 pensioner members and 11,000 deferred members.[635]
- In January, Holophane Retirement Benefits Scheme agreed a £24m buy-in with PIC, covering 95 pensioners and dependants and 74 deferred scheme members.[636]
- In January, the Greater Manchester Pension Fund invested £100m in an investment fund developed and managed by L&G to deliver affordable homes across North West England.[637]
- In January, the Rockwool Limited Penson Scheme agreed a £53m full-scheme buy-in with Royal London.[638]
- In January, the Sanofi Pension Scheme completed a £1.4bn buy-in with L&G, covering 4,900 retirees and 5,600 deferred members.[639]

---

[632] https://www.ipe.com/news/phoenix-eyes-private-capital-deal-to-scale-prt-business/10133458.article
[633] https://www.bankofengland.co.uk/prudential-regulation/publication/2025/november/list-2025-results-report; https://www.theactuary.com/2025/11/26/pra-stress-test-finds-life-insurers-can-absorb-significant-shocks
[634] https://www.ipe.com/news/clarks-footwear-pension-fund-completes-second-buy-in-with-pic/10128054.article
[635] https://www.pensionsage.com/pa/Compass-Group-Pension-Plan-completes-1-5bn-buy-in-with-Standard-Life.php
[636] *Insurance Asset Management*, 15 January 2025.
[637] https://realassets.ipe.com/news/greater-manchester-pension-and-landg-create-affordable-housing-strategy/10128285.article
[638] *Insurance Asset Management*, 24 January 2025.
[639] https://www.ipe.com/news/sanofi-pension-scheme-signs-14bn-buy-in-with-legal-and-general/10128480.article

- In January, the Colthrop Board Mill Pension Scheme executed a £23m buy-in with Aviva, covering 69 deferred members and 152 pensioners.[640]
- In January, Schroders announced that it would run on its DB pension scheme and use 10% of the DB surplus per annum to support the funding of its DC scheme.[641]
- In February, the Lufthansa Group completed buy-ins with Royal London for its three UK DB pension schemes with Royal London in a single integrated transaction valued at £120m, covering 1,200 scheme members.[642]
- In February, the Financial Services Compensation Scheme Pension Scheme agreed a £25m full buy-in with PIC, covering 37 pensioners and 117 deferred members.[643]
- In February, the Tui Group UK Pension Trust executed a £370m buy-in with L&G, securing all remaining pension benefits.[644]
- In February, the Low & Bonar Group Retirement Benefits Scheme completed a £50m full buy-in with Just, covering all remaining uninsured members.[645]
- In February, an unnamed pension scheme agreed an £18m buy-in with Utmost, covering around 270 members of the scheme.[646]
- In February, the Deutz Retirement Benefits Plan executed a £16m buy-in with Just, covering 181 scheme members, including 70 deferred members and 111 pensioners.[647]
- In February, the Geoghegan & Company Staff Pension Scheme completed a £1.5m full scheme buy-in with Just, covering all eight deferred members and eight pensioner members.[648]
- In February, the Boys' Brigade pension scheme secured a £4.5m full scheme buy-in with Just Group, covering 49 members, comprising 15 deferred members and 34 pensioner members.[649]
- In February, M&G completed a £111m bulk purchase annuity transaction with the pension scheme of an unnamed UK-based asset manager, covering 466 pensioners and deferred members.[650]
- In February, Utmost appointed Schroders to manage £400m of its annuity book.[651]
- In March, the Careers Research and Advisory Centre (CRAC) Pension Scheme agreed a £2.8m full scheme buy-in with Just Group, covering 30 deferred members and 10 pensioner members.[652]

---

[640] *Insurance Asset Management*, 30 January 2025.
[641] https://www.ipe.com/news/schroders-uk-pension-scheme-commits-to-running-on/10128566.article
[642] https://www.ipe.com/news/lufthansa-completes-three-in-one-transaction-with-royal-london/10128627.article
[643] *Insurance Asset Management*, 3 February 2025.
[644] *Insurance Asset Management*, 11 February 2025.
[645] *Insurance Asset Management*, 14 February 2025.
[646] *Insurance Asset Management*, 14 February 2025.
[647] *Insurance Asset Management*, 17 February 2025.
[648] *Insurance Asset Management*, 18 February 2025.
[649] *Insurance Asset Management*, 24 February 2025.
[650] https://www.ipe.com/news/mandg-completes-111m-bulk-purchase-annuity-transaction-with-uk-manager/10129075.article
[651] *Insurance Asset Management*, 27 February 2025.
[652] *Insurance Asset Management*, 3 March 2025.

- In March, the Inchcape Motors Pension Scheme secured a £505m buy-in with L&G, covering 2,295 retirees and 5,890 deferred members.[653]
- In March, an unnamed pension scheme completed a £361m full scheme buy-in transaction with Canada Life, covering 850 deferred members and 650 pensioners.[654]
- In March, the A Gomez Limited Retirement Benefits Scheme agreed a £4.8m buy-out with Aviva.[655]
- In March, the Fuller's Defined Benefit Pension Plan secured a full buy-in with Legal & General.[656]
- In March, the Church of Scotland Pension Trustees completed a £75m multi-scheme buy-in with Just Group, covering 1,500 pensioner and dependent members and 850 deferred members.[657]
- In March, Aberdeen announced that it would use part of its DB scheme's £800m surplus to support the funding of its DC scheme.[658]
- In March, Anglo American Services (UK) agreed a £785m combined buy-in with L&G for three of its DB schemes: The Tarmac UK Pension Scheme, the Tarmac 'B' Pension Scheme and the Anglo UK Pension Scheme.[659]
- In March, the BT Pension Scheme (BTPS) executed two longevity swaps totalling £10bn, one for £5bn with Swiss Re and another for £5bn with Reinsurance Group of America. Both swaps used BTPS's existing 'captive' insurer. BTPS had previously executed a £5bn swap with RGA in 2023 and a £16bn swap with PICA in 2016.[660]
- In March, the Clark & Butcher Limited Pension Scheme agreed a £2m full scheme buy-in with Just Group.[661]
- In March, Lloyds Banking Group pension scheme fund trustees completed two new longevity insurance and reinsurance deals, covering £5.1bn of liabilities with Rothesay Life, Pacific Life Re and PICA. The deals cover £2.1bn and £3bn of pensioner liabilities in the Lloyds Bank Pension Scheme No.2 and the HBOS Final Salary Pension Scheme, respectively. Both transactions were structured as insurance policies with Rothesay Life, which bought Scottish Widows' in-force bulk annuity portfolio from Lloyds Banking Group in March 2024, as the insurer. The reinsurance for the transactions was provided by Pacific Life Re for Lloyds No.2 fund and PICA for the HBOS fund. WTW acted as lead adviser for the trustees, with A&O providing legal advice.[662]

[653] *Insurance Asset Management*, 5 March 2025.
[654] *Insurance Asset Management*, 10 March 2025.
[655] *Insurance Asset Management*, 10 March 2025.
[656] *Insurance Asset Management*, 13 March 2025.
[657] *Insurance Asset Management*, 18 March 2025.
[658] https://www.ipe.com/news/abrdn-unlocks-db-surplus-to-fund-dc-contributions/10129243.article
[659] *Insurance Asset Management*, 20 March 2025.
[660] https://www.ipe.com/news/bt-pension-scheme-completes-two-longevity-swaps-totalling-10bn/10129576.article
[661] *Insurance Asset Management*, 28 March 2025.
[662] https://www.ipe.com/news/lloyds-banking-group-pension-funds-strike-two-more-longevity-swaps/10129752.article

- In April, the Englass Pension Scheme agreed a £12m full scheme buy-in with Just Group, covering all 100 scheme members.[663]
- In April, £3bn of pension scheme policies were transferred from Phoenix Life to Aberdeen Life and Pensions, relating to UK private sector DB and DC schemes, as well as UK Local Government Pension Schemes.[664]
- In April, Rothesay completed a £105m full scheme buy-in with the Skipton Building Society (2015) Group Pension Scheme.[665]
- In April, the South East Water Pension Scheme completed £120m buy-in with Just Group, covering 700 pensioner and dependant members and 300 deferred members.[666]
- In April, the Gleaner Pension Scheme agreed a £7.5m buy-in with Aviva, covering all 121 members and all the scheme liabilities.[667]
- In April, the College of Law Pension and Assurance Scheme agreed a £85m buy-in with Royal London, covering all scheme liabilities.[668]
- In April, the OSG Ship Management (UK) Limited Retirement Benefits Plan completed a £16m full scheme buy-in with Aviva, covering 53 members.[669]
- In May, the Cancer Research UK Pension Scheme agreed a £280m buy-in with Standard Life, covering 2,800 members.[670]
- In May, the AQA Education Pension Scheme completed a £120m full scheme buy-in with Rothesay.671
- In May, the Andrew Limited Pension and Life Assurance Plan agreed a £63m bulk annuity policy with Aviva, covering all 570 scheme members.[672]
- In May, the Morrisons Retirement Saver Plan executed a £270m buy-in with Aviva, covering 32,000 deferred members of the RSP Section of the scheme.[673]
- In June, the London Waste Limited Pension Scheme completed a £22m buy-in with Royal London, covering 200 members.[674]
- In June, the Grant Thornton Pensions Fund has secured a £275m buy-in with Royal London, covering 2,200 members. [675]
- In June, the McGregor Construction (Highlands) Limited Pension Plan completed a PPF+ £7m buy-in with Just Group. [676]

[663] *Insurance Asset Management*, 1 April 2025.
[664] https://www.ipe.com/news/aberdeen-takes-on-pension-policies-worth-3bn-from-phoenix-life/10129834.article
[665] *Insurance Asset Management*, 8 April 2025.
[666] *Insurance Asset Management*, 14 April 2025.
[667] *Insurance Asset Management*, 28 April 2025.
[668] *Insurance Asset Management*, 28 April 2025.
[669] *Insurance Asset Management*, 30 April 2025.
[670] *Insurance Asset Management*, 8 May 2025.
[671] *Insurance Asset Management*, 12 May 2025.
[672] *Insurance Asset Management*, 15 May 2025.
[673] *Insurance Asset Management*, 28 May 2025.
[674] *Insurance Asset Management*, 2 June 2025.
[675] *Insurance Asset Management*, 5 June 2025.
[676] *Insurance Asset Management*, 16 June 2025.

- In June, Clara-Pensions completed its fourth superfund transaction by bringing 730 members of the Church Mission Society (CMS) Pension Scheme and £55m in assets into its consolidator vehicle. It is the first deal to use Clara's connected covenant mechanism, which allows the original sponsor to provide a contingent guarantee alongside Clara's own capital contribution.[677]
- In June, Just Group completed buy-ins with two unnamed schemes, totalling £67m and covering all members, including 675 pensioners and 256 deferred members.[678]
- In June, Rothesay completed £20m scheme buy-in with ABC Cinemas
- In June, Rothesay completed a £20m full scheme buy-in with the ABC Cinemas Limited Pension Scheme.[679]
- In June, PIC executed three buy-ins worth £900m with three schemes sponsored by energy technology company, Baker Hughes.[680]
- In June, the Milliken Industrials Limited Pension Plan agreed a £44m buy-in with Royal London, covering 500 members.[681]
- In June, Ultra Electronics Pension Scheme completed a £250m full scheme buy-in with Just Group, covering 1,750 members.[682]
- In July, the Molins UK Pension Fund completed a £249m buy-in deal with Aviva, covering 500 members.[683]
- In July, Utmost Life and Pensions announced that it had completed four separate full-scheme buy-ins so far during the year, covering 1,127 pensioners and dependants as well as 1,365 deferred members. New business premiums for the four deals totalled £177m. The names of the four pension funds were not disclosed.[684]
- In July, the Honda Group UK Pension Scheme agreed an £800m buy-in with Legal & General Assurance Society Limited, covering 1,700 retirees and 3,000 deferred members.[685]
- In July, the Apostolic Church Staff Pension Scheme agreed a £4m full scheme buy-in with Just Group, covering 51 pensioners and 12 deferred members.[686]
- In July, the Huntsman Pension Scheme completed a £205m buy-in with M&G, covering 660 retirees and deferred pensioners.[687]
- In July, Just Group announced a £47.25m inflation linked long-term financing transaction aimed at helping the Lucy Cavendish College, University of

[677] https://www.ipe.com/news/clara-pensions-completes-superfund-deal-with-landmark-not-for-profit-transaction/10131127.article
[678] *Insurance Asset Management*, 23 June 2025.
[679] *Insurance Asset Management*, 24 June 2025.
[680] *Insurance Asset Management*, 26 June 2025.
[681] *Insurance Asset Management*, 27 June 2025.
[682] https://www.ipe.com/news/ultra-electronics-pension-scheme-completes-250m-buy-in-with-just-group/10132662.article
[683] *Insurance Asset Management*, 1 July 2025.
[684] https://www.ipe.com/utmost-life-completes-four-full-scheme-buy-ins/10131526.article
[685] *Insurance Asset Management*, 14 July 2025.
[686] *Insurance Asset Management*, 22 July 2025.
[687] *Insurance Asset Management*, 23 July 2025.

Cambridge, increase the number of students from disadvantaged and underrepresented backgrounds.[688]

- In July, the Institution of Mechanical Engineers Pension Scheme agreed a £40m buy-in with PIC, covering all 200 scheme members.[689]
- In July, DAC Retirement Benefits Scheme executed a £11m full scheme buy-in with Aviva, covering all 15 deferred members and 25 pensioner members.[690]
- In July, the National Grid UK Pension Scheme completed a £900m buy-in with Rothesay, covering 7,130 pensioners and their dependants.[691]
- In July, the ABB Plan executed a £700m buy-in with Aviva, covering 4,450 pensioner members and 2,900 deferred members. The transaction included a £620m in-specie asset transfer of UK and US corporate bonds and UK gilts.[692]
- In July, the Quest UK Pension Scheme completed a £134m bulk purchase annuity buy-in transaction with Aviva, covering 440 members.[693]
- In August, the Terex Pension Scheme completed a buy-in with Aviva, covering all remaining members across three fully segregated sections of the scheme, following a partial pensioner buy-in in 2019.[694]
- In August, the Sedgwick Section of the Marsh McLennan and Mercer (MMC) UK Pension Fund agreed a £1.9bn bulk purchase annuity with Standard Life, covering all 6,500 members. The buy-in included novation of the Section's three existing longevity swaps with Canada Life Re, Munich Re, and PICA from the Guernsey-based insurance captive vehicle, Mercer ICC Limited.[695]
- In August, the WCF Ltd Staff Retirement Benefits Scheme executed a £7.2m buy-in with L&G, covering its remaining 122 deferred members.[696]
- In August, the Rolls-Royce UK Pension Fund completed a £4.3bn buy-in with PIC, covering all remaining liabilities which comprised 15,000 pensioners and 21,000 deferred members.[697]
- In August, the Helaba Pension and Life Assurance Plan agreed a £36m buy-in with PIC, covering all 156 pensioner and deferred members.[698]
- In August, the ROM Group pension scheme secured a £23m full-scheme buy-in with Just Group, covering all 249 members, including 124 deferred and 125 pensioners.[699]

[688] *Insurance Asset Management*, 24 July 2025.
[689] *Insurance Asset Management*, 24 July 2025.
[690] *Insurance Asset Management*, 24 July 2025.
[691] *Insurance Asset Management*, 5 August 2025.
[692] https://www.ipe.com/news/abb-plan-completes-700m-buy-in-with-aviva/10132257.article
[693] *Insurance Asset Management*, 27 August 2025.
[694] *Insurance Asset Management*, 1 August 2025.
[695] https://www.ipe.com/news/mmc-uk-fund-in-19bn-in-bulk-purchase-annuity-deal-with-standard-life/10132075.article
[696] *Insurance Asset Management*, 7 August 2025.
[697] https://www.ipe.com/news/rolls-royce-completes-43bn-full-buy-in-with-pic/10132123.article
[698] *Insurance Asset Management*, 12 August 2025.
[699] *Insurance Asset Management*, 13 August 2025.

- In August, the Misys Retirement Benefits Plan completed a £25m buy-in with L&G, covering 190 deferred and pensioner members.[700]
- In August, the Brother Staff Retirement Benefits Scheme agreed a £56m full scheme buy-in with Just Group, covering all 679 members.[701]
- In August, the SPM Plastics Pension Scheme completed a £4m full buyout with Just Group, covering all 38 scheme members.[702]
- In August, the John Cotton (Mirfield) Limited Retirement Benefits Scheme agreed an £11m full scheme buy-in with Just Group, covering the remaining 105 uninsured members of the scheme.[703]
- In August, two BDO pension schemes completed a £60m buy-in with Just Group, covering more than 1,000 members across both schemes.[704]
- In September, the Philippine National Bank Retirement Benefits Scheme agreed a £1m full scheme buy-in with Just Group.[705]
- In September, two Mativ Holdings pension schemes completed a £105m full scheme buy-in with Rothesay.[706]
- In September, the Pandrol Group Pension Scheme agreed a £45m buy-in with Royal London, covering 200 members.[707]
- In September, the Welcome Break Pension Plan completed a £23m pension buy-in with Just Group.[708]
- In September, Fenwick's pension schemes completed buy-ins valued at £113m with Aviva, covering all remaining benefits for members.[709]
- In September, the Stora Enso UK Group Pension Scheme agreed a £61m buy-in with Royal London, covering 758 members.[710]
- In September, the SG Pension Fund completed a £160m buy-in with Aviva, covering 1,900 members.[711]
- In September, the Amtico Company Pension Scheme secured a £52m full buy-in with Standard Life, covering 425 members.[712]
- In September, the BP Pension Fund agreed a £1.6bn buy-in with L&G.[713]
- In September, the Wolseley Group Retirement Benefits Plan secured a £600m buy-in with Aviva, covering 10,000 members. A £600m buy-in deal with PIC in 2017 covered all of the plan's pensioner liabilities.[714]

---

[700] *Insurance Asset Management*, 14 August 2025.
[701] *Insurance Asset Management*, 18 August 2025.
[702] *Insurance Asset Management*, 21 August 2025.
[703] *Insurance Asset Management*, 26 August 2025.
[704] *Insurance Asset Management*, 29 August 2025.
[705] *Insurance Asset Management*, 1 September 2025.
[706] *Insurance Asset Management*, 9 September 2025.
[707] *Insurance Asset Management*, 10 September 2025.
[708] *Insurance Asset Management*, 12 September 2025.
[709] *Insurance Asset Management*, 19 September 2025.
[710] *Insurance Asset Management*, 23 September 2025.
[711] *Insurance Asset Management*, 24 September 2025.
[712] *Insurance Asset Management*, 25 September 2025.
[713] https://www.ipe.com/news/bp-pension-fund-completes-16bn-buy-in-with-landg/10132821.article
[714] https://www.ipe.com/news/wolseley-group-retirement-benefits-plan-in-600m-buy-in-with-aviva/10133728.article

- In October, an unnamed UK pension scheme, sponsored by a US parent company, executed a £96m buy-in with M&G, covering 1,000 members.[715]
- In October, two pension schemes sponsored by the UK subsidiary of a US-based retail group executed two full-scheme buy-in transactions valued at £130m with Aviva, covering 600 deferred members and 1,200 pensioners and dependants.[716]
- In October, L&G completed two buy-ins totalling £4.6bn with pension schemes sponsored by Ford Motor Company, covering 35,000 retirees.[717]
- In October, the Premdor Crosby Pension Plan completed a £16m bulk purchase annuity transaction with Royal London, covering 181 members.[718]
- In November, the Seabourne Pension Scheme agreed a full scheme buy-in with Just Group.[719]
- In November, the A.G. Barr pension scheme completed a third buy-in with Canada Life valued at £41m and covering 300 pension scheme members.[720]
- In November, the Cosworth Racing Limited Pension Fund executed a £96m buy-in with L&G, covering around 1,000 retirees and deferred members.[721]
- In November, two DFDS-sponsored pension schemes agreed two full scheme buy-ins with Just Group, totalling a combined £70m.[722]
- In November, the Transport Friendly Society Staff Pension Scheme completed a £3.3m full scheme buy-in with Just Group, covering all 30 members.[723]
- In November, two Stonegate Pub Company pension schemes completed buy-ins valued at £62m with Utmost Life and Pensions.[724]
- In November, the Millennium Inorganic Chemicals (UK) Pension Scheme agreed a £30m buy-in with Just Group.[725]
- In November, the Brockhampton pension scheme completed a £40m full buy-in with Just Group, covering around 250 remaining uninsured members.[726]
- In November, the BBC Pension Scheme completed a £6bn longevity swap with Zurich Assurance and Metropolitan Life Insurance Company, covering 21,000 members. This followed a £3bn longevity swap with Zurich in 2020.[727]
- In December, two CF Fertilisers UK pension schemes (Kemira Growhow UK Limited Pension Fund and the Terra Nitrogen UK Limited Pension Scheme) completed a combined £265m buy-in with M&G, covering 1,350 retirees and deferred members.[728]

---

[715] *Insurance Asset Management*, 15 October 2025.
[716] *Insurance Asset Management*, 22 October 2025.
[717] https://www.ipe.com/news/ford-pension-funds-complete-46bn-buy-in-deal-with-landg/10133341.article
[718] *Insurance Asset Management*, 26 October 2025.
[719] *Insurance Asset Management*, 3 November 2025.
[720] *Insurance Asset Management*, 4 November 2025.
[721] *Insurance Asset Management*, 5 November 2025.
[722] *Insurance Asset Management*, 6 November 2025.
[723] *Insurance Asset Management*, 10 November 2025.
[724] *Insurance Asset Management*, 11 November 2025.
[725] *Insurance Asset Management*, 18 November 2025.
[726] *Insurance Asset Management*, 18 November 2025.
[727] https://www.ipe.com/news/bbc-pension-scheme-completes-6bn-longevity-swap/10133815.article
[728] https://www.ipe.com/news/bbc-pension-scheme-completes-6bn-longevity-swap/10133815.article

- In December, the Steamship Insurance Management Services Limited Pension and Assurance Scheme executed a £55m buy-in with Royal London, covering 350 members.[729]
- In December, the Comet Pension Scheme agreed a £330m full-scheme buy-in with Canada Life, covering 4,500 scheme members.[730]
- In December, the Watts Clift Holding Limited Retirement Benefits Scheme executed a £4m buy-in with Aviva, covering all 51 members.[731]
- In December, Lloyds Banking Group Pensions Trustees agreed three longevity risk insurance and reinsurance arrangements totalling £4.8bn with Rothesay Life as the insurer and Prudential Financial as the reinsurer.[732]
- In December, the Stagecoach Pension Scheme transferred its 22,000-member £1.2bn pension fund, which has a large surplus, to Aberdeen. Aberdeen group CEO Jason Windsor said: 'The scheme's strong funding position allows Aberdeen to take on the responsibility for managing the fund and provides the opportunity to enhance member benefits by investing in productive assets. The agreement, which aligns with the UK's goal of making pension capital work harder for the economy, brings £1.2bn in new assets under management and opens up new investment opportunities'.[733]
- In December, Smart Pension completed a £650m bulk transfer of assets and members from the Options Workplace Pension Trust into the Smart Pension Master Trust, as part of a target to reach £10bn in assets under management by 2026.[734]
- In December, the Lincolnshire Co-operative Pension Scheme completed a £107m buy-in with Rothesay Life, covering 2,300 scheme members.[735]
- In December, the Ridsdale Pension and Death Benefit Trust agreed a £7m full scheme buy-in with Just Group, covering 22 pensioners and eight deferred members.[736]
- In December, the Blake Lapthorn Pension Fund executed a £5.7m full scheme buy-in with Aviva, covering 30 deferred members and 22 pensioners.[737]
- In December, the Skanska Pension Fund completed a £525m full buy-in with Standard Life, covering 5,500 members. The deal it included the novation of the fund's existing longevity swap, in place with Zurich Assurance since 2017.[738]

[729] *Insurance Asset Management*, 2 December 2025.
[730] https://www.ipe.com/news/comet-pension-scheme-in-330m-buy-in-with-canada-life/10134179.article
[731] *Insurance Asset Management*, 11 December 2025.
[732] https://www.ipe.com/news/lloyds-banking-group-pension-funds-strike-three-more-longevity-swaps/10134127.article
[733] https://www.ipe.com/news/stagecoach-transfers-12bn-pension-fund-to-aberdeen/10134059.article
[734] https://www.ipe.com/news/smart-pension-adds-650m-to-aum-with-pension-trust-bulk-transfer/10134123.article
[735] *Insurance Asset Management*, 16 December 2025.
[736] *Insurance Asset Management*, 16 December 2025.
[737] *Insurance Asset Management*, 17 December 2025.
[738] https://www.ipe.com/news/skanska-and-peel-ports-pension-funds-secure-member-benefits-with-buy-in-deals/10134345.article

- In December, the Peel Ports Final Salary Pension Scheme agreed a £230m full buy-in with PIC, covering 2,000 members.[739]
- In December, the Oxford Instruments Pension Scheme completed a £213m buy-in with Royal London, covering 1,600 members.[740]
- In December, an unnamed healthcare sector pension scheme completed a £189m buy-in with Canada Life, covering 1,100 deferred members and 600 pensioners.[741]
- In December, Utmost Life and Pensions was bought by US-based JAB Insurance for an undisclosed sum.[742]
- In December, Broadstone announced that its consolidation platform, SM&RT Insure, had reached £1bn in total premiums.[743]

The US PRT market collected $49bn in premiums in 2025 – the fourth year in a row with premiums above $45bn. Buy-in volume was $17.52bn, up from $3.67bn in 2024.[744] Colyar Pridgen of Capital Group argues that the skew in the direction of buy-ins – where the pension fund retains responsibility for making pension payments and acts as the plan fiduciary – is partly explained by ongoing litigation concerns associated with full buy-outs in the US, some of which are discussed below.[745] Prudential added that the increase in buy-ins signalled a strategic shift as plan sponsors sought to lock in rates before full terminations, with more sponsors finding themselves able to terminate plans 'maybe a decade earlier than they had expected'. Smaller deals dominated the US market, with 80% of contracts under $50m.

According to an Arizton research report, published in March 2025, the US pension risk transfer is 'experiencing rapid growth, fueled by regulatory changes, favorable economic conditions, and a heightened focus on reducing financial risks. Key trends include increased plan terminations, the growing adoption of de-risking strategies, rising interest in buy-ins, and the emergence of sidecar solutions. PRT transactions, which encompass lift-outs, plan terminations, and buy-ins, are available in various sizes, with small plan sizes seeing the most significant growth. … The Southern region of the US leads and holds the largest share of the PRT market. This region, which includes states such as Texas, Florida, Georgia, North Carolina, Tennessee, and Virginia, is experiencing significant growth due to its robust base of Fortune 500 companies and a tech-savvy population'. Arizton predicted that the US PRT market will reach $102.38bn by 2030 up from $49.81bn in

[739] https://www.ipe.com/news/skanska-and-peel-ports-pension-funds-secure-member-benefits-with-buy-in-deals/10134345.article
[740] *Insurance Asset Management*, 22 January 2026
[741] *Insurance Asset Management*, 22 December 2025.
[742] *Insurance Asset Management*, 22 December 2025.
[743] https://www.moneymarketing.co.uk/news/broadstone-breaches-1bn-premium-milestone-as-small-scheme-de-risking-surges/
[744] https://www.mercer.com/en-us/insights/retirement/defined-benefit-plans/pension-risk-transfer-market-update-2025-review/
[745] https://www.ai-cio.com/news/more-than-litigation-could-curtail-future-prt-transaction-volume

2024.[746] In 2025, alternative investments accounted for almost one-third (around $2.7trn) of the US insurance industry's assets.[747]

Asset-intensive life reinsurance grew to an all-time high of $160bn in 2025.[748] The main activity related to life insurers' legacy blocks of life policies or annuities for balance sheet management purposes. This was for two reasons, according to Milliman's Prannoy Chaudhury: 'First, the original insurance companies often seek to de-risk from certain policies that have not performed well due to misalignment of original pricing assumptions versus actual experience. Second, these legacy blocks, such as universal life policies or high guarantee deferred annuities, are asset-intensive and attract interest from various asset managers'. The US annuities market (with sales of $385bn in 2023) is much larger than the UK market (with £5.2bn sold in 2023) which is the largest market in Europe. There is also growing interest in this type of deal in Germany and Japan.[749] Greg Winterton adds a third reason: 'US capital markets investors in particular are keen to tap into the "permanent capital" that the life and annuity market provides, and these structures are enabling them to direct this capital into private assets they originate themselves or access via partnerships with other asset management firms'.[750]

Highlights for 2025 in the US included:

- In January, Prudential Financial reinsured a $7bn Japanese whole life block with Prismic Life.[751]
- In March, Talcott Life Re agreed a $3.6bn block reinsurance transaction with Japan Post Insurance.[752]
- On 7 August, President Donald Trump issued an executive order (*Democratizing Access to Alternative Assets for 401(k) Investors*) opening up 401(k) retirement plans to alternative assets, such as 'lifetime income investment strategies including longevity risk-sharing pools' or tontines. Participants in the pool share longevity risks by distributing the assets of those who die as 'mortality credits' to surviving participants. Modern tontines potentially offer higher lifetime income than annuities by eliminating expensive guarantees and operating without third-party insurance.[753]
- In September, an IBM retiree filed a class-action lawsuit against IBM and State Street Investment Management in respect of pension buyout transactions worth $22 billion with Prudential Insurance and covering 132,000 retirees and beneficiaries,

[746] https://insurancenewsnet.com/oarticle/u-s-pension-risk-transfer-market-size-to-hit-102-38-billion-by-2030-arizton
[747] *Insurance Asset Management*, 1 December 2025.
[748] https://lminvestor.com/will-the-us-asset-intensive-life-reinsurance-market-continue-recent-growth-spurt
[749] https://liferisk.news/activity-in-asset-intensive-life-reinsurance-solutions-to-remain-healthy/
[750] Greg Winterton (2026) Will the US Asset Intensive Life Reinsurance Market Continue Recent Growth Spurt?', *Longevity & Mortality Investor*, 22 April, https://lminvestor.com/will-the-us-asset-intensive-life-reinsurance-market-continue-recent-growth-spurt
[751] *Insurance Asset Management*, 27 January 2025.
[752] *Insurance Asset Management*, 31 March 2025.
[753] pionline@e.crainalerts.com, 22 August 2025; https://www.whitehouse.gov/presidential-actions/2025/08/democratizing-access-to-alternative-assets-for-401k-investors/

alleging the transaction with Prudential violated their ERISA fiduciary duties, since Prudential was selected, not because 'it was in the interest of participants but because it was the cheapest' option.[754]

- In September, A federal judge dismissed a lawsuit brought by former General Electric employees challenging the company's decision to transfer $1.7bn pension obligations to Athene Annuity Life Co, ruling that the plaintiffs lacked standing to sue under federal law. The plaintiffs argued Athene was 'not the safest annuity choice available' and that the decision diminished the value of their promised benefits. The judge found that the plaintiffs had not established an 'injury in fact', and stated that beneficiaries in a defined benefit plan 'have no equitable or property interest in the assets of the plan itself, only the amount of the vested benefits that they are entitled to receive'. The finding also noted that the plaintiffs continue to receive all payments owed to them under the insurer-provided annuity and did not allege any imminent risk of nonpayment. Tom Christina, executive director of the ERIC (ERISA Industry Committee) Legal Center said: 'Annuities are lawful and are often a more secure alternative to employer-run pension plans. …We are really pleased with the decision dismissing the complaint in Bueno v. GE. The decision is very thorough and covers all the bases. Let's hope it signals the end of these groundless pension risk transfer cases'.[755]
- In October, a US District Court judge denied motions to dismiss four counts in a consolidated lawsuit against Bristol-Myers Squibb and State Street Investment Management. The lawsuit alleged the company and its fiduciary violated ERISA in completing a pension buyout transaction with two Athene Holding subsidiaries. The judge ruled plaintiffs have shown 'sufficient injury' as a result of the pension buyout and that the transaction with the Athene subsidiary contained sufficient risk to put retirees' benefits in danger. In 2019, Bristol-Myers Squibb transferred $2.6bn in pension plan liabilities of 24,000 participants. The plaintiff claimed the transaction did not meet the requirements of Interpretive Bulletin 95-1, the Department of Labor's Employee Benefits Security Administration guidance related to the fiduciary standards of pension risk transfer transactions that requires plan sponsors to purchase the 'safest annuity available'.[756]
- In October, Eastman Kodak terminated its pension plan and purchased a $1.8bn single premium group annuity contract from Metropolitan Tower Life Insurance, covering 27,000 members.[757]
- In November, RTX Corp. executed the largest US buy-out of 2025, valued at $2.5bn, with Prudential Insurance Co. of America, covering 60,000 retirees and beneficiaries, around one third of the total.[758]

[754] https://www.pionline.com/institutional-investors/pension-risk-transfer/pi-ibm-state-street-prt-lawsuit-pension-buyout-prudential
[755] https://www.ai-cio.com/news/pension-risk-transfer-lawsuit-against-general-electric-dismissed
[756] P&I Daily, pionline@e.crainalerts.com, 1 October 2025
[757] https://www.pionline.com/institutional-investors/insurers/pi-eastman-kodak-annuity-conract-pension-metropolitan/
[758] P&I Daily, pionline@e.crainalerts.com, 14 November 2025

Highlights for 2025 in the Netherlands included:

- In February, Pacific Life Re and Nationale-Nederlanden (NN) Life completed a €2bn longevity swap, covering a block of Dutch in-force individual annuity life policies, with provisions to reinsure future new business via a flow arrangement between the two companies. It was Pacific Life Re's first longevity reinsurance transaction in the Dutch market.[759]
- In April, Zwitserleven concluded a €180m buy-out with Stichting Pensioenfonds Trespa, covering 1,300 participants.
- In April, Nedlloyd, the €950m closed pension scheme of the Dutch branch of shipping firm Maersk, completed a buyout with insurer Zwitserleven. The scheme had 8,200 mostly retired members.[760]
- In May, FrieslandCampina completed a €1.5bn buyout with Achmea Pensioen & Levensverzekeringen N.V. (Achmea Pension & Life), covering 8,000 former employees of Friesland Foods and FrieslandCampina. [761]
- In August, NN Life & Pensions completed a €4bn longevity risk transfer deal with Prudential Financial Inc, covering 96,000 policyholders. PFI first entered the Dutch longevity reinsurance market in 2023, when it executed an earlier agreement with NN Life & Pensions, a subsidiary of NN Group.[762]
- In August, ASR announced it was looking at reinsuring its buyouts of pension funds against longevity risk to reduce the negative impact on solvency. Its four existing buyouts of pension funds, valued at €2.9bn, have reduced its solvency by four percentage points. The insurer calculated that longevity risk reinsurance halves the impact of buyouts on solvency, while it also giving a higher return on the buyouts themselves. Its four buyouts have an internal rate of return of 12% (annual proceeds of the buyouts divided by the required invested capital). Reinsurance would raise the return to 14% or 15%. After an initial negative effect on solvency, €1bn in buyout capital provides a net €10m of capital annually. The four buyouts therefore yield the insurer €30m annually, prior to reinsurance.[763]
- In December, De Nederlandsche Bank (DNB) reported that Dutch life insurers had taken on €7bn in pension liabilities through buy-outs in 2024-25.[764]

In March, Vedra Pensions announced that had agreed a pension buy-out deal with Hauck Aufhäuser Lampe Privatbank. This was first transaction involving the pension liabilities of a bank in Germany. Vedra took over the pension corporation (Rentnergesellschaft) which was established by the bank to offload its pension liabilities, with assets held in a two-tier contractual trust arrangement (CTA). Lampe Asset Management will manage the liquid assets, while trust assets will be invested under the umbrella of the Vedra Spezialfonds. The specific amount of the deal was not disclosed. Pension risk experts Funding Solutions

[759] https://www.lifeinsuranceinternational.com/news/pacific-life-re-nn-life-longevity-swap/
[760] https://www.ipe.com/news/nedlloyd-fund-concludes-950m-buyout-with-zwitserleven/10129954.article
[761] *Insurance Asset Management*, 28 May 2025.
[762] https://www.ipe.com/news/nn-life-and-pensions-in-4bn-longevity-reinsurance-deal-with-prudential-financial/10132111.article
[763] https://www.ipe.com/news/asr-eyes-buyout-reinsurance/10132292.article
[764] *Insurance Asset Management*, 16 December 2025.

Deutschland expects to implement €1bn in pension buy-outs during the year. WTW set up a pension buy-out shop during the year. German companies have around €700bn in pension liabilities on their balance sheets. Pension buyout firm Deutsche Betriebsrenten Holding (DBR) expects €10bn in buy-out transactions in 2025-26, while VEDRA anticipates €60bn in transactions over the next five to 10 years.[765] In July, Vedra Pensions took over the pension liabilities of Frankfurt-based OWH, formerly the European subsidiary of Russia's sanctioned lender VTB Bank.[766] Later in the year, it did buy-outs with AST Deutschland, OWH SE and Hypo Real Estate Holding.[767]

Also in July, WTW entered the German buyout market, with an emphasis on small and medium-sized enterprises with pension liabilities in the range of €50m to €500m. Some SMEs have come under pressure from US tariffs and are involved in mergers and acquisitions. As part of this process, they are considering offloading their pension liabilities via buyouts. Larger SMEs (Mittelstände) are also viewing buyouts as a potential de-risking tool. According to WTW, large DAX-listed companies are prepared to talk about buyouts, but are 'not mentally ready on the topic of the impact on reputation'. Foreign companies with direct promises (Direktzusage) on their balance sheets are also investigating buyouts. WTW's structure comprises a foundation (Stiftung), a pension holding company, and a pension corporation – the vehicle used to transfer liabilities – supported by a pension trust (Pensionsfonds) and a CTA. The foundation, independent from both the holding and the pension corporation, is used to pay benefits over time, while the pension holding integrates the pension corporation through share deals. WTW says it structures assets for buyouts through existing fund platforms, drawing on actuarial, administration and payroll services, as well as global investment operations. The portfolio focus is on private markets and illiquid assets to deliver long-term premium, liquidity and returns in volatile markets. WTW also acts as an outsourced chief investment officer (OCIO) for the pension corporation within the fund-based buyout solution, with portfolios implemented through sub-fund structures. WTW uses Munich Re to hedge risks associated with pension promises in buyout deals. The reinsurance solution offers guarantees on pension products not bound by Germany's maximum interest rate (Höchstrechnungszins), which has risen from 0.25% to 1% during the year. With Munich Re's reinsurance solution in place, guaranteed benefits are calculated on the basis of market interest rates.[768] In addition, WTW and state bank Landesbank Baden-Württemberg (LBBW) are collaborating on the funding of pension de-risking transactions, with LBBW acting as house bank for WTW's funding platform, which includes contractual trust arrangements, Pensionsfonds and pension buyouts.[769]

[765] https://www.ipe.com/analysis/germany-expects-new-wave-of-buyout-transactions-tipped-to-reach-60bn/10129313.article
[766] https://www.ipe.com/news/german-firms-ramp-up-pension-buyout-activity/10131450.article
[767] https://www.ipe.com/news/ubs-offloads-german-credit-suisse-pension-book-in-de-risking-deal/10133723.article
[768] https://www.ipe.com/news/wtw-targets-small-and-medium-sized-pension-funds-for-buyout-deals/10132531.article
[769] https://www.ipe.com/news/german-plan-sponsors-opt-for-staged-pension-de-risking/10134377.article

In October, Schroders announced that it was strengthening its position in the emerging German pension buyout market. It reported that it had won an outsourced chief investment officer (OCIO) mandate from pension buyout boutique Funding Solutions Deutschland (FSD) to manage the assets of a pension corporation. Schroders will implement a cash flow-driven investment (CDI) strategy by investing in a range of asset classes and construct a derivatives portfolio for liability-driven investments to fund the pension corporation's liabilities. FSD executed around a dozen buy-outs during the year totalling €500m, e.g., with Wintershall Dea, owned by BASF and investment group LetterOne. BlackRock has also become active in a market which is expected to have annual transactions of around €60bn in the next few years.[770]

In October, Mercer also announced that it was strengthened its position in the pension buyout market through a strategic partnership with Vedra Pensions. Mercer will provide advisory services on investments, portfolio construction, trust solutions and OCIO mandates. In exchange, Vedra will establish and operate pension corporations.[771]

In November, UBS transferred the pension liabilities of Credit Suisse's German subsidiaries to DBR, as part of the post-merger consolidation of the two banks. The buy-out was in excess of €100m. The assets and liabilities were transferred a newly created pension corporation and placed within the Allianz Treuhand contractual trust arrangement to ensure assets remain ring-fenced.[772]

The growth of the German pension buyout market will concentrate on the funded segment of the market. Around 60% of Germany's €750bn in pension liabilities remain unfunded, making buyouts virtually impossible. DAX companies hold €300bn in pension liabilities, with funding ratios of 87%. Non-DAX companies have much lower funding levels. Also the legal framework for buyout deals through pension corporations is regarded as currently inadequate, since they are currently governed by corporate law but not insurance law.[773] Gunnar Hasselmann, pension consulting partner at PwC Deutschland, added that volatile markets and a prolonged period of economic stagnation were intensifying the desire to reduce pension risk, but were also making traditional transactions harder to execute. As a result, many sponsors were looking at 'stretched' solutions, such as buy-ins executed in tranches or hybrid structures that spread the balance sheet impact over time.[774]

In March, Resolution Life signed a $9.7bn reinsurance agreement with Protective, a US subsidiary of Dai-ichi Life Holdings. Protective ceded blocks of structured settlement annuities and secondary guaranteed universal life policies currently in runoff to Resolution Life. Resolution Life said: 'With the recent announcement of Nippon Life's acquisition of

[770] https://www.ipe.com/news/schroders-ramps-up-activity-in-fast-evolving-german-buyout-space/10133126.article
[771] https://www.ipe.com/news/mercer-expands-in-german-pension-buyout-market/10133334.article
[772] https://www.ipe.com/news/ubs-offloads-german-credit-suisse-pension-book-in-de-risking-deal/10133723.article
[773] https://www.ipe.com/analysis/german-buyout-market-eyes-next-growth-phase-as-standards-take-shape/10134329.article
[774] https://www.ipe.com/news/german-plan-sponsors-opt-for-staged-pension-de-risking/10134377.article

Resolution Life, we will continue to accelerate our growth in the highly active, multi-trillion-dollar global life and annuity consolidation sector'.[775]

In March, Japan Post Insurance announced that it was considering investing around $2bn into a new reinsurance sidecar[776] co-investment vehicle sponsored by Global Atlantic Financial Group, the US life, retirement and annuities insurance and reinsurance company owned by Kohlberg Kravis Roberts (KKR), the US global private-equity and investment company.[777]

In May, Pacific Life Re announced a second asset-intensive reinsurance agreement with Japan's Tokio Marine & Nichido Life Insurance Company (Anshin Life). The deal again covered in-force whole of life policies and will provide Anshin Life with a method to reduce long-term interest rate risk and enhance its asset liability management capabilities.[778]

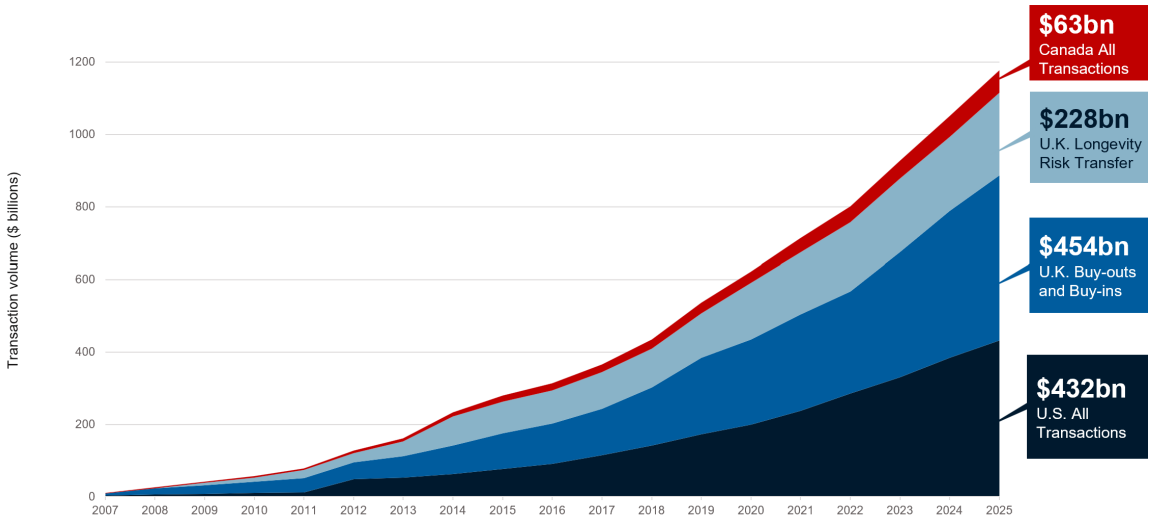
In June, Resolution Life completed a $1bn block reinsurance transaction with an unnamed life insurer in Hong Kong. The agreement involved a portfolio of participating whole life and annuity policies and transferred the risks associated with the guaranteed benefits of these policies, including market, policyholder behavior, and mortality risks to Resolution Life.[779]

In September, Athene has announced that it intended to enter a block reinsurance transaction with Sony Life.[780]

Figure 3 shows the growth of the global market in longevity risk transfer between 2007 and 2025. A total of $1,177bn in transactions have been completed during this period in the UK, the US and Canada (which comprises the vast majority of the global market).

[775] https://www.reinsurancene.ws/resolution-life-signs-9-7bn-reinsurance-agreement-with-protective/
[776] https://www.artemis.bm/reinsurance-sidecars/
[777] https://www.artemis.bm/news/japan-post-insurance-could-invest-up-to-2bn-in-new-global-atlantic-reinsurance-sidecar/
[778] https://www.pacificlifere.com/news/pacific-life-re-announces-new-asset-intensive-reinsurance-deal-with-tokio-marine-and-nichido-life.html
[779] https://uk.investing.com/news/company-news/resolution-life-secures-1bn-hong-kong-reinsurance-deal-93CH-4120646
[780] Insurance Asset Management, 29 September 2025

**Figure 3: Cumulative pension risk transfers by product and country, $bn, 2007-2025**




Data in USD billions. Cumulative totals. Sources: PFI, LIMRA, Hymans Robertson, and WTW, 31 December 2025.

## Securitizing mortality risk

A number of insurers and reinsurers have used the capital markets to securitize some of the mortality risk on their book of business, in the form of what have become known as mortality-linked (or mortality catastrophe) bonds. Swiss Re has been the most active participant in the market, issuing the first security in 2003, known as Vita I.[781] Vita I was a $400m principal-at-risk variable rate note, where the investors' principal was at risk in certain extreme mortality risk scenarios in exchange for quarterly coupon payments of USD three-month LIBOR[782] plus a spread of 135 basis points. The bond matured on 1 January 2007.

There has been some recent innovation in this market. An example of this is the La Vie Re Limited (Series 2020-1) mortality catastrophe bond issued by the Minnesota Life Insurance Company in October 2020. The bond covers the US and is the first indemnity 144A excess mortality bond that models the cedants' portfolio on a loss-ratio basis. The modelling was conducted by Risk Management Solutions which developed an indemnity trigger on loss ratios.[783]

[781] Swiss Re obtains USD 400 million of extreme mortality risk coverage its first life securitization, news release, 8 December 2003;
https://www.swissre.com/dam/jcr:edf6b706-4c0b-4fc1-85bf-46a338e36208/pr_20031208_en.pdf
[782] LIBOR, the London Interbank Offered Rate, was a benchmark interest rate at which major global banks lent to one another. It was replaced by the Secured Overnight Financing Rate (SOFR) on 30 June 2023;
https://www.investopedia.com/terms/l/libor.asp
[783] https://www.insurancebusinessmag.com/asia/news/breaking-news/rms-collaborates-on-new-mortality-catastrophe-bond-239994.aspx

Guy Carpenter (GC), the global risk and reinsurance specialist, argues that risk transfer, reinsurance and insurance-linked securities sectors are well-placed to assist in dealing with climate change.[784] The company highlights catastrophe bonds as a key risk transfer and resilience financing tool for governments and public sector entities. Climate change increases the possibility of severe weather-related losses as well as demographic movements associated with rising sea levels, posing challenges to governments and entities exposed to these changes. GC calls for 'a rethink of how catastrophic events are funded and a greater use of public-private partnerships to manage risk'. According to the company, capital markets have the ability to absorb catastrophe and severe weather-related risks and diversify them away, allowing reinsurers and insurers to leverage its depth and liquidity and help make public sector entities more secure and better able to manage the financial exposure of climate-related risks.[785]

**Setbacks**

As mentioned before, not all paths to progress are smooth. In recent years, this has been particularly true currently in the largest market dealing with micro-longevity risk, namely life settlements.[786] The life settlements market has been dogged by systematic underestimates of policy holders' life expectancies by certain medical underwriters, issues concerning premium financing, frauds, and ethical issues associated with 'profiting' from individuals dying and policies maturing. In December 2009, Goldman Sachs announced it was closing down its QxX.LS index. This was partly because of the reputational issues associated with life settlements, but mainly because of insufficient commercial activity in the index. While the ethical issues are no different in substance from those relating to the macro-longevity market (see, e.g., Blake and Harrison, 2008), the micro-longevity market needs to learn some important lessons from the macro-longevity (i.e., PRT) market. The macro-longevity market has been very successful at promoting good basic research on the analysis of the stochastic mortality forecasting models it uses and putting these models into the public domain and has also been much more transparent with the data it uses. This suggests a way forward for the life settlements micro-longevity market.

Another setback, this time to the macro-longevity market, occurred in April 2012 when a number of investment banks – Credit Suisse, Nomura and UBS – pulled out of the longevity risk transfer market as a result of additional capital requirements under Basel III. Investment banks had already been disadvantaged in this market by the Dodd-Frank Act which prevented US banks and their affiliates from entering longevity swaps and synthetic

[784] Climate change is discussed in more detail below.
[785] Steve Evans (2020) Risk transfer, reinsurance key to address reality of climate change: Guy Carpenter, *Artemis*, 11 March; https://www.artemis.bm/news/risk-transfer-reinsurance-key-to-address-reality-of-climate-change-guy-carpenter/
[786] The market for micro-longevity risk trades assets involving a small number of lives. In the case of life settlements, for example, the products involve individual lives and hence are subject to a significant degree of idiosyncratic mortality risk. This contrasts with the market for macro-longevity risk which deals with pension plans and annuity books and hence involves a large number of lives: here idiosyncratic mortality risk is much less important than systematic mortality risk which is essentially the trend risk of getting life expectancy projections wrong.

trades in life settlements. At around the same time, however, a number of insurers and reinsurers entered the market, e.g., PICA, SCOR and Munich Re. The following year witnessed the start of a process of consolidation in the insurance industry. In August 2013, Lucida was purchased by L&G for £150m; at the time, it had 31,000 pensioners on its books and £1.4bn in pension assets. In February 2014, the buy-out business of MetLife, which entered the market in 2007 and acquired the pension assets of 20,000 pensioners worth £3bn, was sold to Rothesay Life for an undisclosed sum, bringing its total assets to £10bn.

In December 2013, Goldman Sachs sold the majority of its stake in Rothesay Life to Blackstone (28.5%), the Government of Singapore Investment Corporation (GIC) (28.5%), and MassMutual (7%), due to the new regulatory capital requirements faced by banks and insurers.[787] In October 2020, Blackstone sold its 36% stake in Rothesay Life to GIC and MassMutual for an undisclosed sum. This raised GIC and MassMutual's stakes to 49% each and values Rothesay Life at £5.8bn, with £56bn in assets under management.[788]

**Academic contributions**

At the same time as these practical developments in the capital markets were taking place, academics were continuing to make progress on theoretical developments, building on the original idea of using longevity bonds to hedge longevity risk in the capital markets (Blake and Burrows (2001)). These included:

- Design and pricing of longevity bonds and other longevity-linked products (e.g., Blake et al. (2006a,b, 2014), Bauer (2006), Bauer and Ruβ (2006), Antolin and Bloomestein (2007), Bauer and Kramer (2007), Denuit et al. (2007), Barbarin (2008), Bauer et al. (2010b), Chen and Cummins (2010), Kogure and Kurachi (2010), Bravo (2011), Dowd et al. (2011a), Mayhew and Smith (2011), Zhou et al. (2011, 2013, 2015), Chen et al. (2013, 2017, 2025c), Shen and Siu (2013), Denuit et al. (2015), Dong and Wong (2015), Hunt and Blake (2015), Milevsky and Salisbury (2015), Yang et al. (2015), Wang and Li (2016), Lin et al. (2017b), Blake (2018), D'Amato et al. (2018a), Leung et al. (2018), MacMinn and Richter (2018), Li and Tang (2019), Bahl and Sabanis (2021), Dagpunar (2021), Mayhew et al. (2021), Jevtić et al. (2021), Tang and Li (2021), Bozikas et al. (2022), Arık et al. (2023), Li et al. (2023), Xie and Shang (2024), Xu et al. (2024), Costabile et al. (2025), So et al. (2025), Li (2025), Garces et al. (2026))
- Design and pricing of longevity-linked derivatives (e.g., Shang et al. (2011), Lin et al. (2013), Wang and Yang (2013), Chuang and Brockett (2014), Bravo and Nunes (2021), Kung et al. (2021b), Landriault et al. (2026)) and specifically

[787] In August 2017, Goldman Sachs sold its remaining stake in Rothesay Life to a consortium comprising US buy-out firm Blackstone, Singapore's sovereign wealth fund GIC, and US life insurer MassMutual in a deal valuing Rothesay Life at around £2bn; http://www.cityam.com/269996/goldman-sachs-sells-final-stake-2bn-rothesay-life

[788] Blackstone offloads stake in Rothesay Life, *Pionline*, 1 October; https://www.pionline.com/money-management/blackstone-offloads-stake-rothesay-life

survivor/longevity swaps (e.g., Dowd et al. (2006), Wang et al. (2013, 2015), Zhou and Li (2013), De Jong and Ferris (2019), Li et al. (2019), Chen et al. (2022b)), survivor/longevity forwards and swaptions (e.g., Dawson et al. (2009, 2010), Zeddouk and Devolder (2020a)), *q*-forwards (e.g., Deng et. Al. (2012), Barrieu and Veraart (2016)), mortality options (e.g., Milevsky and Promislow (2001), Schmeck and Schmidli (2021), Zhou and Li (2021), Lin and Tsai (2023)), guaranteed annuity options (e.g., Gao et al. (2015), Grozen and Mamon (2025,2026)), longevity bond options (e.g., Xu et al. (2020), and derivatives related to extreme mortality events (e.g., Huang et al. (2023b))

- Pricing longevity and mortality risk (e.g., Olivieri and Pitacco (2008), Bayraktar et al. (2009), Chen et al. (2010), Li (2010), Li et al. (2023))
- The pricing of longevity-related guarantees (e.g., Yang et al. (2008))
- The pricing and hedging of life settlements (e.g., Deng et al. (2011), Brockett et al. (2013), Zhu and Bauer (2013), MacMinn and Zhu (2017), Kung et al. (2021a))
- Longevity and mortality indices (e.g., Denuit (2009), Li et al. (2011), Chan et al. (2014), Tan et al. (2014), Ortiz et al. (2023), Bacinello et al. (2024), Zhou et al. (2024))
- Securitization of longevity risk (e.g., Dahl (2004), Chen and Cox (2009), Cowley and Cummins (2005), Lin and Cox (2005), Cairns et al. (2006a), Cox and Lin (2007), Biffis and Blake (2010, 2013, 2014), Wills and Sherris (2010), Lane (2011), Mazonas et al. (2011), Blake et al. (2013), Yang and Wang (2013), Michaelson and Mulholland (2014), Li et al. (2017c), MacMinn and Brockett (2017), Bugler et al. (2021), Börger et al. (2023), Zeddouk and Devolder (2023))
- Management and hedging of longevity risk (e.g., Dahl and Møller (2006), Friedberg and Webb (2007), Cocco and Gomes (2008), Tsai et al. (2010), Wang et al. (2010), Cairns (2011, 2013), Coughlan et al. (2011), Koijen et al. (2011), Li and Hardy (2011), and Tzeng et al. (2011), Wang et al. (2010, 2011b), Ngai and Sherris (2011), Barrieu et al. (2012), International Monetary Fund (2012), Li and Luo (2012), Cox et al. (2013a,b), Qiao and Sherris (2013), Cairns et al. (2014), Lin and Tsai (2014, 2020a,b), Zelenko (2014), Zhu and Bauer (2014), Liu and Li (2016, 2017, 2018, 2021), Blackburn et al. (2017), Li et al. (2017a, 2021, 2023), Wong et al. (2017), Zhou and Li (2017), D'Amato et al. (2018b), Li (2018), Tsai and Liang (2018), Hanbali et al. (2019), Zhou and Li (2019, 2020), Balasooriya et al. (2020), Sherris et al. (2020), Levantesi et al. (2020), Börger et al. (2021a), Broeders et al. (2021), Cairns and El Boukfaoui (2021), Hsieh et al. (2021), Kessler (2021), MacMinn and Zhu (2021), Choulli et al. (2021), Siu and Liu (2021), Clemente et al. (2022), Feng et al. (2022), Tan et al. (2022), Chen et al. (2023a,b,c), Yang and Zhou (2023), Kallestrup-Lamb and Laursen (2024), Armstrong and Dalby (2025), Coughlan (2025), Shen et al. (2025), Zhou et al. (2025))
- Mortality data and modeling, mortality term structure[789] modeling, and mortality forecasting (e.g., Heligman and Pollard (1980), Hobcraft et al. (1982), Arriaga (1984), Pollard (1987), Alho (1990,1991), Lee and Carter (1992), Wilmoth (1995, 2000), Thatcher et al. (1998), Wilmoth and Horiuchi (1999), Booth et al. (2002a,b,

[789] The mortality term structure is the two-dimensional surface showing projected mortality rates at different ages for different future years.

2006), Brouhns et al. (2002a,b, 2005), Oeppen and Vaupel (2002), Renshaw and Haberman (2003a,b,c, 2006, 2008), Vaupel and Canudas-Romo (2003), Currie et al. (2004), Biffis (2005), Bongaarts (2005), Czado et al. (2005), Cairns et al. (2006b, 2008, 2009, 2011a), De Jong and Tickle (2006), Koissi et al (2006), Pedroza (2006), Schrager (2006), Delwarde et al. (2007), Bauer et al. (2008), Blake et al. (2008), Booth and Tickle (2008), Gourieroux and Monfort (2008), Hari et al. (2008), Kuang, et al. (2008), Haberman and Renshaw (2009, 2011, 2012, 2013), Hatzopoulos and Haberman (2009, 2011), Li et al. (2009, 2013, 2015a,b, 2016, 2017b, 2020a,b, 2021a, 2024a,b, 2025a,b), Rau et al. (2008), Plat (2009a,b), Wang and Preston (2009), Bauer et al. (2010a), Biffis and Blake (2010), Biffis et al. (2010), Cox et al. (2010), Debonneuil (2010), Dowd et al. (2010a,b, 2020), Lin and Tzeng (2010), Murphy (2010), Yang et al. (2010), Coelho and Nunes (2011), Currie (2011, 2016, 2020, 2023), D'Amato et al. (2011, 2012a,b), Ediev (2011, 2021), Gaille and Sherris (2011), Li and Chan (2011), Milidonis et al. (2011), Russo et al. (2011), Russolillo et al. (2011), Sweeting (2011), Wang et al. (2011a), Yue and Huang (2011), Zhu and Bauer (2011), Aleksic and Börger (2012), Hainaut (2012, 2018, 2023), O'Hare and Li (2012, 2017), Shang (2012, 2019, 2024), Wilmoth et al. (2012), Bell and Jones (2013), Blackburn and Sherris (2013), Hyndman et al. (2013), Kleinow and Cairns (2013), Mitchell et al. (2013), Alai and Sherris (2014), Nielsen and Nielsen (2014), Hunt and Blake (2014, 2020a,b, 2021a,b,c,d), Villegas and Haberman (2014), Danesi at al. (2015), Hunt and Villegas (2015, 2023), Tomas and Planchet (2015), Leng and Peng (2016), Schinzinger et al. (2016), van Berkum et al. (2016), Bergeron-Boucher et al. (2017, 2024), Beutner et al. (2017), Deprez et al. (2017), Gbari et al. (2017), Kleinow and Richards (2017), Li and Lu (2017), Li and O'Hare (2017), Mavros et al. (2017), Milidonis and Efthymiou (2017), Neves et al. (2017), Shang and Hyndman (2017), Tsai and Lin (2017a,b), Börger and Schupp (2018), Chen and Millossovich (2018), Debonneuil et al. (2018b), Ludkovski et al. (2018), McCarthy (2018), Pascariu et al. (2018, 2019, 2020), Salhi, and Thérond (2018), Shang and Haberman (2018, 2020a, 2024, 2025), Venter and Şahın (2018), Villegas et al. (2018), Wong et al. (2018, 2023), Apicella et al. (2019, 2024), Basellini and Camarda (2019), Guibert et al. (2019, 2025), Hilton et al. (2019), Liu et al. (2019), Nigri et al. (2019, 2021), Pitacco (2019), Yang et al. (2019), Zhou (2019), Atance et al. (2020), Balland et al. (2020), Basellini et al. (2020, 2023), Gibbs et al. (2020), Huang et al. (2020), Milevsky (2020), Njenga and Sherris (2020), Richards et al. (2019, 2020), Santolino (2020, 2023), Zeddouk and Devolder (2020b), Barigou et al. (2021, 2023), Börger et al. (2021b), Boumezoued (2021), Boumezoued and Elfassihi (2021), Diao et al. (2021), Dodd et al. (2021), Doukhan et al. (2021), Guo and Bauer (2021), Gao and Shi (2021), Ghalehjooghi and Lyu (2021), He et al. (2021), Hilton et al. (2021), Li and Kogure (2021), Li and Lyu (2021), Lin et al. (2021), McCarthy and Wang (2021a), Medford (2021), Odhiambo et al. (2021), Pavía and Lledó (2021), Perla et al. (2021), Rabbi and Mazzuco (2021), Rizzi et al. (2021), Ševčíková and Raftery (2021), Shimizu et al. (2021), Su and Yue (2021), Tsai and Cheng (2021), Yue et al. (2021), Wang et al. (2021a,b), Yan et al. (2021), Zhou and Ji (2021), Albrecher et al. (2022), Aliverti et al. (2022), Awad et al. (2022), Beyaztas and Shang (2022), Bjerre (2022), Caraballo et al. (2022), Chandra and Abdullah (2022), Chen and Khaliq (2022),

Djeundje et al. (2022), Huang et al. (2022), Jallbjørn and Jarner (2022), Kessy et al. (2022), Kularatne et al. (2022), Li and Chen (2022), Miyata and Matsuyama (2022), Odhiambo et al. (2022), Redzwan and Ramli (2022), Schnürch and Korn (2022), Scognamiglio (2022a,b), Sliwka and Socha (2022), Spreeuw et al. (2022), SriDaran et al. (2022), Tang et al. (2022, 2025), Wang and Chan (2022), Zhou et al. (2022), Zhou and Li (2022), Zhu and Bauer (2022), Alonso-García (2023), Bégin et al. (2023b, 2025), Carannante et al. (2023, 2024a,b, 2025), Cardillo et al. (2023), Diao et al. (2023), Dyrting and Taylor (2023), Gowen et al. (2023), Haberman (2023), Jena et al. (2023), Jones et al. (2023), Levantesi et al. (2024), Li (2023, 2024), Liu and Li (2023), Liu and Shi (2023), Lu and Zhu (2023), Marino et al. (2023), McCarthy and Wang (2023), Odhiambo (2023), Orwat-Acedańska (2023), Rakhmawan et al. (2023), Scognamiglio and Marino (2023), Shimizu (2023), Ungolo et al. (2023, 2024), Wang et al. (2023b), Xiao et al. (2023), Zhu and Zhou (2023), Boateng et al. (2024), Bufalo and Nigri (2024), del Olmo and Navarro (2024), Dimai and Brabec (2024), Garrido et al. (2024), Hsiao et al. (2024), Kogure and Takamatsu (2024), Lam and Wang (2024), Mok et al. (2024), Mitsuda and Shimizu (2024), Richards (2024), Risk and Ludkovski (2024), Rostami and Zadeh (2024), Shen et al. (2024), Qiao et al. (2024), Wang (2024), Wu et al. (2024), Ashwin and Scott (2025), Atance et al. (2025), Bi and Zeng (2025), Boonen and Chens (2025), Chiu et al (2025), Dastranj and Kolář (2025), De Mori et al. (2025), Diana et al. (2025), Dimai (2025b), Dror (2025), Fu et al. (2025), Graziani and Nigri (2025), Grossman and Wilson (2025), Guo and Li (2025a,b), Haas and Sunde (2025), Koichubekov et al. (2025), Meng et al. (2025), Shull et al. (2025), Zhang and Zhuang (2025), Zheng et al. (2025), Zhou and Zhu (2025), Zuo et al. (2025), Faragher et al. (2026), Lakehal et al. (2026), Leong and Yue (2026), Ludkovski et al. (2026), Qiao et al. (2026), Sakr et al. (2026), Szentkereszti and Vékás (2026))

- Multi-population mortality modeling (e.g., Darkiewicz and Hoedemakers (2004), Li and Lee (2005), Cairns et al. (2011b), Dowd et al. (2011b), Jarner and Kryger (2011), Njenga and Sherris (2011), Torri and Vaupel (2012), Li (2013), Raftery et al. (2013, 2014), D'Amato et al. (2014), Zhou et al. (2014), Antonio et al. (2015), Chen et al. (2015), Kleinow (2015), Shang (2016), Yang et al. (2016), Antonio et al. (2017), Biffis et al. (2017), Li et al. (2015c, 2016, 2017d), De Jong et al. (2016, 2020), Enchev et al. (2017), van Berkum et al. (2017), Villegas et al. (2017), Zhu et al. (2017), Diaz et al. (2018), Hunt and Blake (2018), Kang et al. (2018), Pitt et al. (2018), Wang et al. (2018), Jevtić and Regis (2019), Henshaw et al. (2020), Jarner and Jallbjørn (2020, 2022), Shi et al. (2020), Wong et al. (2020), Chang et al. (2021), Li and Shi (2021a,b), Li et al. (2021b), Liu (2021), Lu et al. (2021), Özen and Şahin (2021), Richman and Wüthrich (2021), Schnürch et al. (2021), Shapovalov et al. (2021), Wen et al. (2021), Yang et al. (2021), Zhou and Ji (2021), Djeundje et al. (2022), Fokeer and Narsoo (2022), Gungah and Narsoo (2022), Jiao et al. (2022), Kung et al. (2022), Lin and Tsai (2022), Shang et al. (2022), Venter and Şahin (2022), Chang and Shi (2023), Debón et al. (2023, 2025), Jevtić et al. (2023), Perla and Scognamiglio (2023), Roshani et al. (2023), Shang and Haberman (2020b), Shi et al. (2023), Wang et al. (2023c), Corsaro et al. (2024), De Mori et al. (2024), Euthum et al. (2024), Lizzi (2024), Robben and Antonio (2024), Atance

and Debón (2025), Cheng et al. (2025), Daly and Hall (2025), Devolder et al. (2025), Câmpeanu and Meng (2026))

- Mortality modeling by cause-of-death, educational attainment, social class, special patterns, Covid-19, climate change, vitality, etc (e.g., Beard (1971), McNown and Rogers (1992), Christensen and Vaupel (1996), Gutterman and Vanderhoof (1998), Di Cesare and Murphy (2009), Richards (2009), Hanewald (2011), Murphy and Di Cesare (2012), Arnold and Sherris (2013, 2015, 2016), Janssen et al. (2013), Alai et al. (2014a), Gourieroux and Lu (2015), Alai et al. (2018), Boumezoued et al. (2018), Yue et al. (2018), Li et al. (2019), Dutton et al. (2019), Kjærgaard et al. (2019, 2020), Cairns et al. (2020), Cupido et al. (2020, 2024), Kallestrup-Lamb et al. (2020), Lourés and Cairns (2020, 2021), Arnold and Glushko (2021), Lyu et al. (2021, 2023), Nusselder et al. (2022), Robben et al. (2022, 2025), Schnürch et al. (2022), Stefanucci and Mazzuco (2022), Cadena and Denuit (2023), Huang et al. (2023a), Jallbjørn et al. (2023), Katsiferis et al. (2023), Navarro and Requena (2023), Pichler and Uhlig (2023), Villegas et al. (2023, 2025), Wen et al. (2023), Zhang et al. (2023), Cairns et al. (2024a,b), Delbrouck and Alonso-García (2024), Şahin and Özen (2024), Aragona et al. (2025), Arik et al. (2025), Baldi et al. (2025), Dimai (2025a), Dong et al. (2025), Feliciangeli et al. (2025), Goes et al. (2025), Sifre-Armengol et al. (2025), van Berkum et al. (2025), Varga (2025), Zhu et al. (2025), Aprea et al. (2026))
- Population, births and deaths data – and modeling (e.g., Richards (2008), Cairns et al. (2016), Boumezoued et al. (2019, 2020), Boumezoued (2021), Boumezoued and Elfassihi (2021), Cheng et al. (2022), Hwang and Kim (2023), Tang et al. (2023), Rubilar-Torrealba et al. (2024), Pavía and Lledó (2025))
- Longevity inequality and health (e.g., Mayhew and Smith (2014, 2021), Debón et al. (2017), Mayhew et al. (2020, 2024), Álvarez et al. (2021), Li and Hyndman (2021), Sanzenbacher et al. (2021), Katsiferis et al. (2023), Mayhew (2023), Strozza et al. (2024, 2025), Yue et al. (2024a))
- Longevity risk and financial innovation (improvements in the analysis and design of longevity-linked products) (e.g., Gong and Webb (2010), Stevens at al. (2010), Richter and Weber (2011), Cocco and Gomes (2012), Brown and Warshawsky (2013), Bernhardt and Donnelly (2019), Chen and Rach (2019), Chen et al. (2019), Weinert and Gründl (2021))
- Reverse or equity release mortgages (e.g., Wang et al. (2008), Huang et al. (2011), Yang (2011), Alai et al. (2014b), Kogure et al. (2014), Shao et al. (2015), Lee et al. (2018), Dowd et al. (2019), Di Lorenzo et al. (2022), Buckner et al. (2024), Apicella et al. (2025))
- Longevity risk in investment portfolios and asset-liability management (e.g., Milevsky and Young (2007), Menoncin (2008), Horneff et al. (2008, 2009, 2010, 2015), Maurer et al. (2013), Aro and Pennanen (2017), Gemmo et al. (2020), Maffra et al. (2021), Rogalla (2021), Lin et al. (2023), Jang, Owadally, and Clare (2024))
- Longevity risk in life insurance, pension plans, pension systems, annuities and long-term care, etc (e.g., Milevsky (2005), Huang et al. (2009, 2012, 2017), Richards et al. (2013, 2014), Aro (2014), Bisetti and Favero (2014), Donnelly (2014), Lin et al. (2014, 2015, 2017a), Ai et al. (2015), Wan and Bertschi (2015), Ai et al. (2017),

Hunt and Blake (2017), Bravo and El Mekkaoui de Freitas (2018), Bruszas et al. (2018), Cox et al. (2018), Debonneuil et al. (2018a), Hsieh et al. (2018), Ignatieva et al. (2018), Kurtbegu (2018), Mayhew et al. (2018), Balter et al. (2020, 2021, 2023), Chen et al. (2020, 2022a, 2024, 2025a,b,c,d), Olivieri and Pitacco (2020, 2022), Wen et al. (2020), Ayuso et al. (2021), Balter et al. (2021), Cox et al. (2021), De Rosa et al. (2021), Dowd et al. (2021), Kogure et al. (2021), Lee et al. (2021), Leung et al. (2021), McCarthy and Wang (2021b), Richards (2021), van Berkum et al. (2021), Bakar and Büyükyazıc (2022), Berstein and Morales (2021), Bravo and Ayuso (2021), Bravo et al. (2021, 2023), Bravo (2022), Cairns et al. (2022), Carannante et al. (2022), Coppola et al. (2022), Feng et al. (2022), Li et al. (2022), Li and Kara (2022), Olivieri et al. (2022), Sharma et al. (2022), Zhou et al. (2022), Rong et al. (2023), Agarwal et al. (2023), Bégin et al. (2023a), Bravo et al. (2023), Horneff et al. (2023), Lin et al. (2023), Lledó et al. (2023), Mrad et al. (2023), Wang et al. (2023c), Navarro and Atance (2024), Nguyen et al. (2024), Zhang et al. (2023), Atance et al. (2024a), Atance and Navarro (2024b), Bégin et al. (2024), Deelstra et al. (2024), Fuentes et al. (2024), Kabuche et al. (2024), Gasimova et al. (2024), Olivieri and Tabakova (2024), Yang et al. (2024), Yue et al. (2024b), Zhou et al. (2024), Aragona et al. (2025), Di Palo (2025), Feng et al. (2025), Hanbali (2025), Pittarello et al. (2025), Ramsay et al. (2025), Lin and Shi (2026), Maggistro et al. (2026), Zhao et al. (2026)).

## Looking into the future

There are a large number of factors that will influence the future of the PRT market. We now examine the key ones.

### *Peak cash flows*

Pension funds not only need to have assets sufficient to meet liabilities (i.e., be fully funded), they need the cash flows on those assets to match pension payments as they fall due. Absent this, assets would have to be sold (possibly at unfavourable prices) in order to make the payments. It is especially significant for closed schemes which can no longer rely on contributions from active members to help to make pension payments. Further, once a scheme is closed, it matures rapidly and the duration of the liabilities falls. It is important therefore for such a scheme to work out the timing of peak cash flows and then insure that sufficient cash flow generating assets are in place during this period. In the UK, the Pensions Regulator requires schemes to set a long-term funding objective.

For a lot of UK schemes, research by TPR indicates that pension payments may already be close to their peak. Many of these schemes will have been preparing for this by switching out of growth assets, such as equities, into cash-flow generating assets, such as government (gilts) and high-quality high-yielding corporate bonds, as part of liability-driven investment strategy which might also have involved hedging the purchase of these bonds against falling interest rates. As the peak approaches, then more precise cashflow matching is required.

It has been estimated that around £1trn out of a total of £2.2trn UK pension liabilities are exposed to (i.e., were not hedged against) changes in interest rates and inflation. In addition, there will be between £250-£300bn of additional exposure as schemes deleverage their LDI portfolios in preparation for making cash payments.

Given the narrow range of suitable cash-flow generating assets, this is likely to drive up their prices. The total size of the sterling investment grade corporate bond market is only around £375bn. Although issuance has increased significantly with the fall the interest rates due to quantitative easing – £60bn of new sterling corporate bonds were issued in 2019, for example – quality and yields have also fallen. UK pension funds have been forced to increase their exposure to both BBB credit, the lowest class of investment grade bonds, and to sterling bonds issued by non-UK-based corporates (which account for around 50% of sterling issuance). UK pension funds have also looked to source suitable bonds in the Eurozone and US corporate bond markets and then hedge the currency risk.[790]

In August 2020, LGIM launched a range of secure income asset funds aimed at small DB pension schemes following a cashflow-driven investment strategy. The funds have an open-ended pooled structure with a three-year lock-in period and target a return of gilts +2.5% per annum over a rolling three-year period. LGIM has also launched separate unit-linked life funds for senior real estate debt, investment grade infrastructure debt, investment grade private corporate debt, and sub-investment grade infrastructure debt and sub-investment grade private corporate debt, which are suitable for investment horizons of at least seven years.[791]

***The volatility of life expectancy trends***

In 2016, the UK Office for National Statistics (ONS) reported that longevity improvements rates at very high ages have slowed down since 2011. A number of reasons were put forward to explain this: short-term reasons, such as lower increases in health service[792] and long-term care spending as part of the government's 'austerity' spending cuts following the Global Financial Crisis; and longer term reasons, such as increasing deaths from neurodegenerative disorders, such as dementia and Alzheimer's disease,[793] and the fact that most of the improvement in life expectancy in the 1990s and 2000s was due to lower

[790] Nikesh Patel and Arif Saad (2020) Viewpoint: The tipping point for UK pension schemes, *IPE*, 20 November; https://www.ipe.com/viewpoint-the-tipping-point-for-uk-pension-schemes/
[791] LGIM launches secure income range for DB plans, *IPE*, 3 August 2020.
[792] A University of York study published in 2021 estimated that for every 1% real increase in healthcare spending there was a 0.5% improvement in population mortality (cited in Murray et al. (2022); https://bmjopen.bmj.com/content/bmjopen/11/10/e046417.full.pdf).
[793] Dementia is a syndrome, not a disease. A syndrome is a group of symptoms that does not have a definitive diagnosis. Dementia is a group of symptoms that affects mental cognitive tasks such as memory and reasoning. Dementia is an umbrella term that Alzheimer's disease can fall under. It can occur due to a variety of conditions, the most common of which, accounting for up to 70% of cases, is Alzheimer's disease. Other diseases which cause dementia are Parkinson's and Huntington's. See: Dementia and Alzheimer's: What Are the Differences?; https://www.healthline.com/health/alzheimers-disease/difference-dementia-alzheimers

mortality from circulatory causes, such as heart disease, arising from the widespread use of statins and there was no longer scope for further improvement.[794] In 2018, the UK ONS reported that healthy life expectancy – the average number of years lived in 'very good' or 'good' general health – fell for women and rose for men, comparing 2015-17 and 2009-11 data. For men, healthy life expectancy at birth increased by five months to 63.1 years, while it fell by three months to 63.6 years for women. At birth, UK men and women can expect to live with a disability for 16.5 and 20.9 years, respectively.[795]

This prompted a debate in the UK about the volatility of life expectancy trends. Mortality improvements for England & Wales males aged 50-89 averaged 0.7% p.a. over the period 2011-16, compared with 3.1% p.a. between 2001-10, 1.8% between 1975-2000, and 0.7% between 1961-75.[796] At the time, the UK actuarial profession took the view that the sharp reduction in the trend improvement was permanent. The Mortality Projections Model of the Institute and Faculty of Actuaries' Continuous Mortality Investigation – which covers England & Wales – published in March 2019 predicted that the average cohort life expectancy of a 65-year old man in 2018 was 19.8 years, down by five months (or 2.4%) compared with 2017; the corresponding figure for a 65-year old woman was 22.4 years, also down by 5 months (or 2.1%).[797] The CMI's best estimate life expectancy growth for the next 40 years from 2022 is between 2.9 and 4.5 years, which is lower than the 6.8 years experienced over the previous 40 years.[798]

Figure 4 shows life expectancy from birth in the UK since 1980. The ONS found that between 2018 and 2020 there was 'virtually no improvement in life expectancy' for women which equalled 82.9 years in 2020. For men, life expectancy in 2020 was 79 years and had actually fallen back to 2012-14 levels. This is the first decline since the 1980s – and it could fall further following the pandemic.[799]

---

[794] Anthony Hilton (2016) Life line, *Pensions World*, May; *Accounting for Pensions: Reflecting the cost of pension freedoms and life expectancy*, Xafinity Punter Southall, April 2018; page 12 of Willis Towers Watson *De-risking Report 2020*, January. See also www.bbc.com/news/health-4060825.

[795] Stephanie Baxter (2018) 'Healthy' life expectancy falls for women, but improves for men, *Professional Adviser*, 13 December.

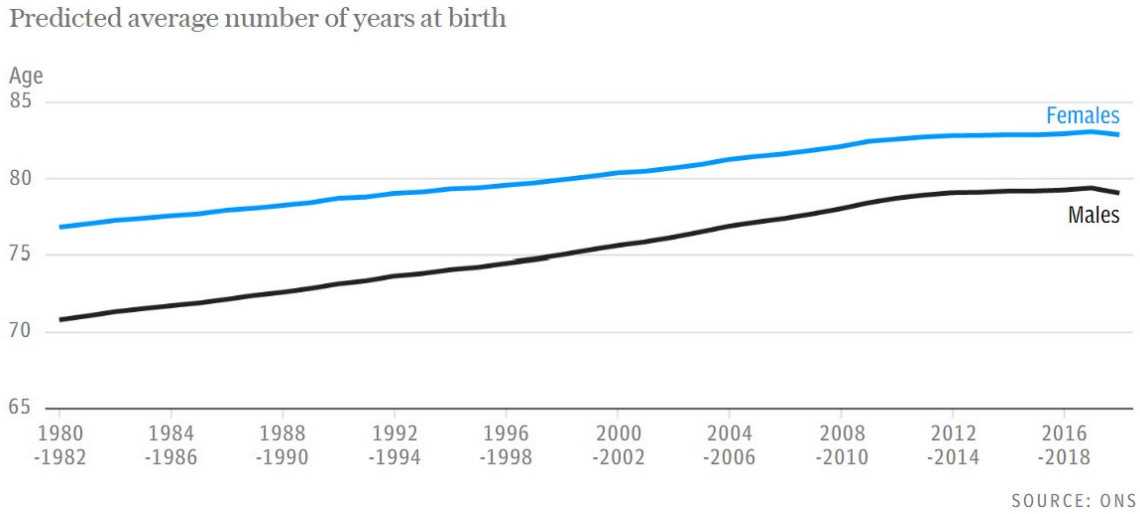
[796] Page 6 of 'Mortality improvements in the next decade, Discussion hosted by SIAS and the CMI Mortality Projections Committee', 11 April 2017, Staple Inn Hall, London; https://www.actuaries.org.uk/system/files/field/document/CMI%20SIAS%20meeting%202017-04-11%20-%20Mortality%20imps%20in%20the%20next%20decade%20v04.pdf

[797] Rachel Fixen (2019) UK schemes set for 2.5% fall in liabilities after CMI model revamp, *IPE*, 8 March.

[798] Murray et al. (2022).

[799] Szu Ping Chan (2023) Why the state pension age may never again reach 70, *Daily Telegraph*, 3 December; https://www.telegraph.co.uk/business/2022/12/03/why-state-pension-age-may-never-reach-70

**Figure 4: Life expectancy at birth in the UK**




Source: https://www.telegraph.co.uk/business/2022/12/03/why-state-pension-age-may-never-reach-70/

In 2022, the UK government introduced a target to improve healthy life expectancy by 5 years by 2035.[800] Les Mayhew (2023)[801] has estimated that a one year improvement in healthy life expectancy would add 4.5 months to UK life expectancy (LE) and 3.4 months to working lives, whilst reducing taxes by around 0.5%. If the government target were to be chieved, it would add 23 months to LE, 17 months to work expectancy and reduce taxes by 2.4%. However, a number of organizations, such as the Health Foundation,[802] have cast doubt on whether the target can be achieved, not least because 'years of improvement in life expectancy after 2010 have come to a halt', as pointed out by Les Mayhew (2025).[803]

Particularly, striking is what has been happening in the US where the life expectancy of the average American fell from 78.85 years in 2019 to 76.98 years in 2020 and 76.44 years in 2021, a net reduction of 2.41 years, according to a study by Masters et al. (2022). The study said that most of the decline was due to the pandemic, with the rest explained by a rise in accidental deaths and deaths from drug overdoses, heart disease, chronic liver disease and cirrhosis. In contrast, 21 peer countries[804] averaged a smaller decrease in life expectancy between 2019 and 2020 (0.55 years) and a 0.26-year *increase* between 2020

[800]https://www.gov.uk/government/publications/levelling-up-the-united-kingdom; https://www.health.org.uk/reports-and-analysis/analysis/healthy-life-expectancy-target-the-scale-of-the-challenge

[801] Les Mayhew (2023) Counting the Cost of Inequality, *Journal of Demographic Economics*, 89(3):395-418.

[802] https://www.health.org.uk/reports-and-analysis/analysis/healthy-life-expectancy-target-the-scale-of-the-challenge

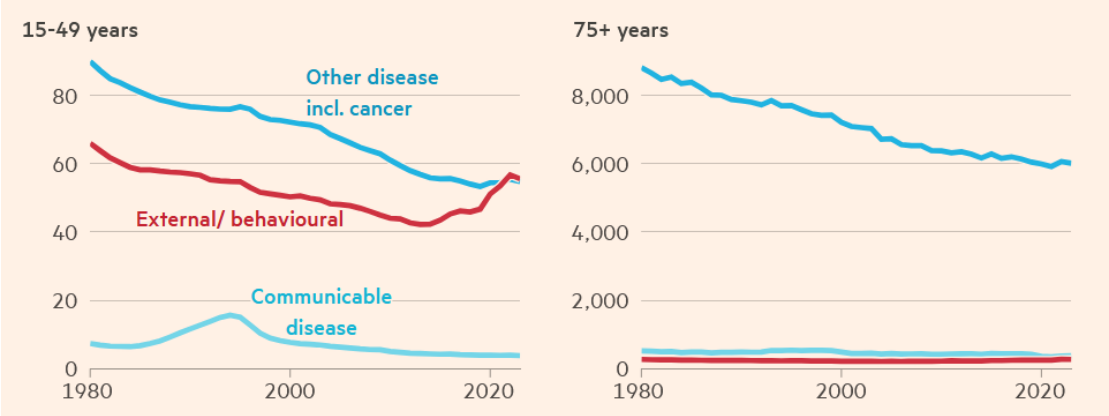
[803] Les Mayhew (2025) Impact of Stalled Life Expectancy on Health and Economic Inactivity in the UK and the Case for Prevention, *Risks*, 13(11): 211.

[804] Australia, Austria, Belgium, Canada, Denmark, England and Wales, Finland, France, Germany, Israel, Italy, Netherlands, New Zealand, Northern Ireland, Norway, Portugal, Scotland, South Korea, Spain, Sweden, and Switzerland.

and 2021. This increased the gap in life expectancy between the US and the peer countries to around five years.[805]

A study of global mortality trends by the Institute for Health Metrics and Evaluation found that mortality rates in the 15-49 age group have been increasing in many high-income countries, particularly the US, Canada and the UK. As shown in Figure 5, this is explained by 'external/behavioural' factors or what is commonly known as 'deaths of despair', premature loss of life through suicide, drugs or alcohol. Glei et al. (2024) examined whether these 'deaths of despair' were due to psychological or economic distress or due to long-term unemployment and social isolation – they found that the latter were the more likely explanations.[806]

**Figure 5: Annual mortality rate per 100,000 people in high-income countries, by age group and cause of death**




Source: Human Mortality Database; https://www.ft.com/content/eac9e5e4-5401-4411-9a69-c037b609c0cb

Time will tell if there has been a permanent change in trend in these countries or if the trend will again reverse in response to advances in applied biotechnology and in regenerative medicine, as discussed below. Nevertheless, Olshansky et al. (2024) argue that humans are approaching a biologically based limit to life. The biggest boosts to longevity have already occurred through successful efforts to combat disease, leaving the damaging effects of aging as the main obstacle to further extension. Lead author S. Jay Olshansky of the UIC School of Public Health said: 'Most people alive today at older ages are living on time that was manufactured by medicine. But these medical Band-Aids are producing fewer years of life even though they're occurring at an accelerated pace, implying that the period of rapid increases in life expectancy is now documented to be over. That also means extending life expectancy even more by reducing disease could be harmful, if those additional years aren't healthy years. We should now shift our focus to efforts that slow aging and extend healthspan. While more people may reach 100 years and

[805] https://www.nytimes.com/2022/08/31/health/life-expectancy-covid-pandemic.html
[806] Dana A. Glei, Chioun Lee, Casey L. Brown and Maxine Weinstein (2024) 'Are Employment and Social Integration More Strongly Associated with Deaths of Despair than Psychological or Economic Distress?', *Social Science & Medicine*, 357: 117197.

beyond in this century, those cases will remain outliers that won't move average life expectancy significantly higher. But [this] doesn't rule out that medicine and science can produce further benefits. There may be more immediate potential in improving quality of life at older ages instead of extending life. More investment should be made in geroscience — the biology of aging, which may hold the seeds of the next wave of health and life extension. This is a glass ceiling, not a brick wall. There's plenty of room for improvement: for reducing risk factors, working to eliminate disparities and encouraging people to adopt healthier lifestyles – all of which can enable people to live longer and healthier. We can push through this glass health and longevity ceiling with geroscience and efforts to slow the effects of aging'.[807]

In December 2018, the CMI published a new version of its SAPS (Self-Administered Pension Scheme) data set. This covers UK members of DB pension schemes and the data has been collected since 2000. The S3 series mortality tables for the period 2009-16 showed that life expectancy in this select group was still increasing when compared with the S2 series mortality tables for the period 2004-11.[808] One year's increase in life expectancy can raise a pension scheme's liabilities by 4%,[809] while if longevity risk is measured on a whole-of-life basis, the potential increase in pensions over 30-40 years could represent an increase in liabilities of 15-20%.[810] In March 2020, the CMI reported that mortality rates in England and Wales were on average 3.8% lower in 2019 than in 2018, the highest year-on-year reduction since 2011. This shows that mortality rates are volatile and confirms the point that longevity trends can go both ways.[811]

The long-term impact of Covid also needs to be taken into account. The ONS estimated that there were 7.2% or 44,255 more deaths in the UK in 2022, compared with the previous five-year average (excluding 2020). There were 8.6% or 28,024 more deaths in the first six months of 2023 than expected. The causes of these excess deaths include the direct effects of Covid-19 infection, as well indirect consequences, such as late diagnosis and treatment of diseases, and the growing NHS backlog of operations.[812] Analysis by consultancy Lane Clark & Peacock (LCP) predicted that, as a consequence, life expectancies could reduce by around nine months, which would equate to a £100m lower funding requirement for a £3bn pension scheme.[813] Consultancy Hymans Robertson conjecture that if Covid becomes

[807] https://www.pensionpolicyinternational.com/despite-medical-advances-life-expectancy-gains-are-slowing/
[808] XPS Pensions (2019), New 'SAPS3' mortality tables – a confusing message?, *Briefing Note No.3*, January.
[809] Mark Dunne (2020) Breaking free: Bulk annuities, *Portfolio Institutional*, 24 January; https://www.portfolio-institutional.co.uk/features/breaking-free/
[810] Willis Towers Watson *De-risking Report 2020*, January (p.9).
[811] Susanna Rust (2020) Highest reduction in mortality rates in England and Wales since 2011, IPE, 2 March.
[812] Pearson-Stuttard et al. (2024).
[813] Jonathan Stapleton (2022) Mortality trend shift could cut funding requirements, *Professional Pensions*, 21 November; https://www.professionalpensions.com/news/4060538/mortality-trend-shift-cut-funding-requirements

another endemic disease, with similar severity to the flu, this would mean an additional 20,000 – 30,000 death each year.[814]

In February 2024, the CMI announced that it would give no weight to mortality data for pandemic years 2020 and 2021 in its future life expectancy and mortality projections. It said that 'While mortality experience in 2020 and 2021 will affect actuarial calculations, mortality in both of those years was exceptional and is unlikely to be indicative of future mortality. …We are conscious that the outlook for mortality remains uncertain and there is a range of reasonable projection methods and projected mortality rates'. It also said that more recent mortality has been less volatile and is more likely to be indicative of future mortality. Standardised mortality rates based on registered deaths in England and Wales in 2023 were similar to the 2015-2019 average and lower than in 2020, 2021 and 2022.[815]

In February 2026, the UK Office for National Statistics announced that during 2022-2024: males in the UK could expect to spend 60.7 years (77% of life) in 'good' general health, compared with 60.9 years (73%) for females – which represents decreases of 1.8 and 2.5 years, respectively, compared with 2019-2021; healthy life expectancy (HLE) at birth in the UK, for both males and females, decreased to its lowest level since 2011-2013; and England continued to have the highest HLE at birth among UK constituent countries for both males (60.9 years) and females (61.3 years); Scotland had the lowest for males (59.1 years) and Wales had the lowest for females (58.5 years). The decline in HLE appears to have started in 2019[816] – and World Health Organization data shows a similar pattern in other parts of the world, with the global average HLE at birth falling from 63.5 in 2019 to 61.9 in 2021.[817] Analysis by Club Vita published in January 2026, covering Canada, the US and the UK, reveals that in both Canada and the US, mortality rates have been increasing among adults aged 25-44 for over a decade. In the UK, mortality rates for this age group declined until the Covid-19 pandemic but showed the lowest rate of improvement among adults in the decade prior to the pandemic; they again declined throughout 2025 and into 2026.[818] Amy Walker, an actuary at Club Vita, suggested that this indicated that the effects of Covid-19 were over: '2025 is the first year that we're seeing fairly clear evidence that mortality is returning to pre-pandemic levels. That said, it's still too early to say what mortality will do going forward, particularly for under 65s. Keeping an eye on trends in 2026 will be vitally important'.[819]

In March 2026, a study by Abrams et al (2026) found that US life expectancy may have peaked. The study used cause-of-death data from 1979 to 2023 and found that people born between 1970 and 1985 – late Gen Xers and early Millennials – were experiencing higher mortality rates than earlier generations. The middle Baby Boomers (born in the 1950s)

---

[814] Murray et al. (2022).
[815] https://www.ipe.com/news/cmi-ignores-mortality-data-for-pandemic-years/10071586.article
[816] https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/healthandlifeexpectancies/bulletins/healthstatelifeexpectanciesuk/between2011to2013and2022to2024
[817] https://data.who.int/indicators/i/48D9B0C/C64284D
[818] https://www.clubvita.net/uk/news-and-insights/comparison-of-working-age-mortality-21-century_
[819] https://lminvestor.com/mortality-rates-scrutiny-as-excess-deaths-data-contradicts-cmi/

could represent a turning point. Earlier generations experienced steady declines in mortality, with fewer deaths from heart disease, cancer and accidents. However, for later generations, mortality has been rising for a number of reasons: cardiovascular disease, cancer (particularly colon cancer) and external causes like drug overdoses, traffic accidents, suicides and homicides. One reason for this is lifestyle and social pressures, including increasing obesity, poor diets and the stress of modern life. Another reason is economic inequality, with job insecurity and limited access to quality healthcare adding to stress, which, in turn, can lead to chronic disease, substance use and mental health problems. The isolating impact of Covid-19 pandemic magnified the pressures. Leah Abrams, lead author of the paper said: 'These patterns are interconnected. They reflect a web of social, economic and biological factors', adding that 'the situation is worrying, since cancer and heart disease are typically uncommon among people in their 30s and 40s. If these cohorts are showing worse mortality trends already, what's going to happen when they reach their 60s if nothing changes?'. Kyle Umipig from Longevity.Technology comments: 'For the longevity sector, these findings are a clear signal. Medical innovation alone isn't enough; human lifespan is as much about environment, society and generational dynamics as it is about biology. Younger generations are facing what might be the first sustained reversal in US life expectancy in modern history. To truly extend lifespan and healthspan, interventions must be holistic. Addressing social inequalities, promoting healthy lifestyles and ensuring access to preventive care are essential. Otherwise, the decades of progress in longevity risk stalling… or even rolling back'.[820]

In April 2026, the World Health Organization estimated that, between 2030 and 2050, climate change could cause about 250,000 additional deaths every year from undernutrition, malaria, diarrhoea and heat stress. Older adults are more vulnerable to heatwaves, air pollution and extreme weather, which increase heart attacks, strokes and respiratory disease. Children are more exposed to undernutrition, infectious diseases and the long-term impact of toxic air on lung and brain development. People in low-income and climate-vulnerable countries often face these threats with the weakest health and social protection systems. The World Economic Forum has warned that climate change acts as a risk multiplier on longevity, interacting with existing burdens such as non-communicable diseases, food insecurity and unsafe housing. It threatens to slow, and in some places reverse, the life expectancy gains of the last century.[821]

All this makes it increasingly challenging for those operating in the PRT market to derive the best estimate of both the trend improvement in life expectancy and the volatility around the trend.

[820] Abrams, L., Bramajo, O., van Raalte, A., Myrskylä, M., and Mehta, N.K. (2026) 'Insights into US Life Expectancy Stagnation from Birth Cohort Mortality Dynamics, *Proc. Natl. Acad. Sci. U.S.A.*, 123 (11) e2519356123, https://doi.org/10.1073/pnas.2519356123; https://longevity.technology/news/longevity-wake-up-call-for-younger-generations; https://www.sciencealert.com/study-reveals-a-turning-point-in-us-life-expectancy

[821] https://www.pensionpolicyinternational.com/why-climate-action-matters-for-healthy-longevity/

### *Population aging*

There is an emerging global debate covering a wider set of demographic issues than just longevity risk. The debate has centred on population aging and its implications. One aspect of population aging is declining fertility which soon translates into an increase in the average age of the population. One key reason for declining fertility is the choice made by women in developed countries to have fewer children than previous generations.

This has been exacerbated by the Covid-19 pandemic, according to the United Nations. Birth rates have fallen due to 'a postponement of childbearing in the face of the uncertainty regarding the disease and its economic impacts, disruptions in marriage patterns and family formation, and disruptions in the availability and access to sexual and reproductive health-care services, including family planning'.[822] Edward Stanley, an analyst at Morgan Stanley, commented that 'Prior financial crises suggest the suppressant on birth rates can last for three to four years. Moreover, using the 1917-20 Spanish Flu example as a loose proxy, the recovery in the birth rate in 2021 is unlikely to be linear. In 1917-20, with each new wave of virus came a renewed downturn in subsequent births'. The pandemic caused the fertility rate in the UK to plunge to a new low of 1.6 per woman in 2020. Stanley predicts that 70% of the world's population will be below the replacement rate within five years, adding significantly to population aging.[823]

Another explanation for declining fertility is male sperm counts falling so fast across the world that the human race could be infertile within 50 years. There has been a 60% decline in the sperm count of Western men between 1973 and 2011, with 15% of young Western men with a sperm count low enough to impair fertility. A variety of explanations have been put forward to explain this: lifestyle factors, such as alcohol, smoking, stress, obesity, antidepressants, and high doses of ibuprofen; pesticides and industrial pollutants getting into the food chain; sunscreen, containing endocrine-disrupting UV filters; non-stick frying pans, containing poly- and perfluoroalkyl substances; tight underpants; oestrogen in the water supply from the female contraceptive pill; and electromagnetic radiation from wi-fi routers.[824,825]

Figure 6 shows UN projections of fertility rates out to 2050. Prior to 1970, the average woman had five children. She now has 2.3 which is just above the 'replacement rate' of 2.1, the level which stabilizes the population. Globally, fertility rates are expected to fall to the replacement rate by 2050. Fertility rates in Europe, North America, Australia and New Zealand have been below replacement since the mid-1970s. The OECD reported in

[822] https://www.telegraph.co.uk/business/2022/07/13/europe-faces-ageing-population-nightmare-absolute-collapse
[823] https://www.telegraph.co.uk/business/2021/07/16/birth-rate-will-take-years-recover-covid-baby-bust/
[824] India Sturgis (2018) Prepare for Spermageddon, *Daily Telegraph Magazine*, 27 January.
[825] Melanie Guldi and Chris M. Herbst (2017) found that increased high-speed internet access explained at least 7% of the decline in the US teenage birth rate from 1999 to 2007 (Melanie Guldi and Chris M. Herbst (2017) Offline effects of online connecting, *Journal of Population Economics*, 30(1): 69-91; https://www.jstor.org/stable/48698133)

2024 that the birth rate in the 38 most industrialised countries had fallen to 1.5 in 2022 and that these countries should prepare for a 'lower fertility future': 'This decline will change the face of societies, communities and families and potentially have large effects on economic growth and prosperity'. The OECD explained the decline in family formation in terms of a 'second demographic transition', a trend shift in attitudes towards greater individual freedom and alternative life goals and living arrangements.[826]

**Figure 6: Fertility rates are slowing down globally**

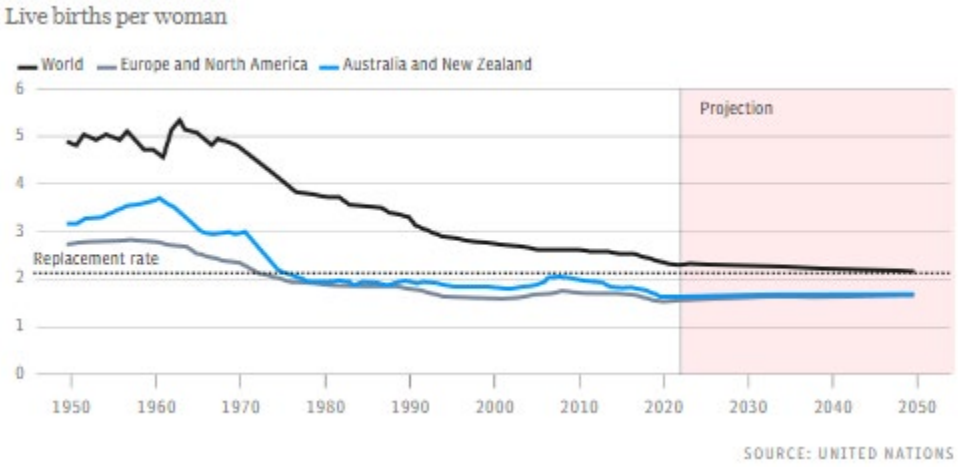
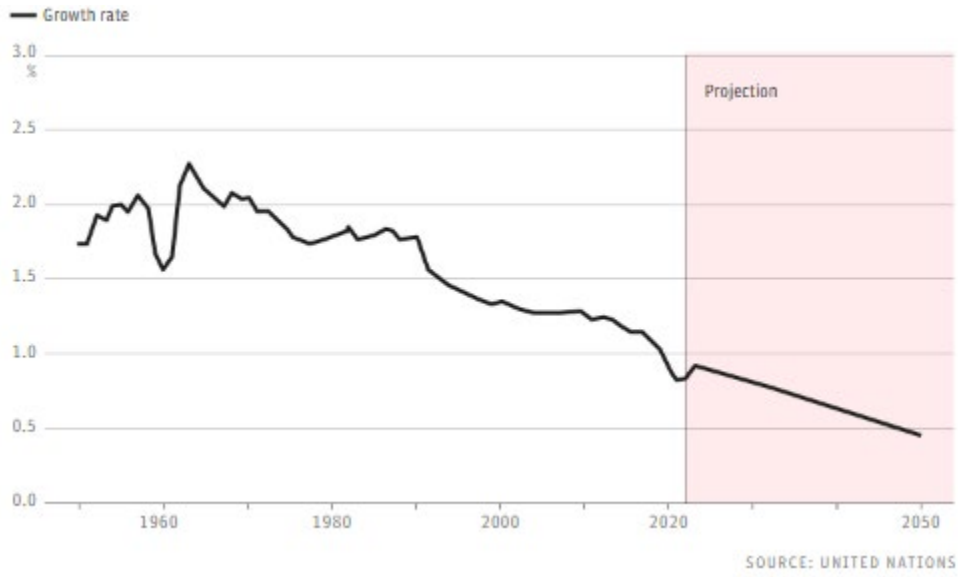



**Figure 7: Global population growth is slowing**

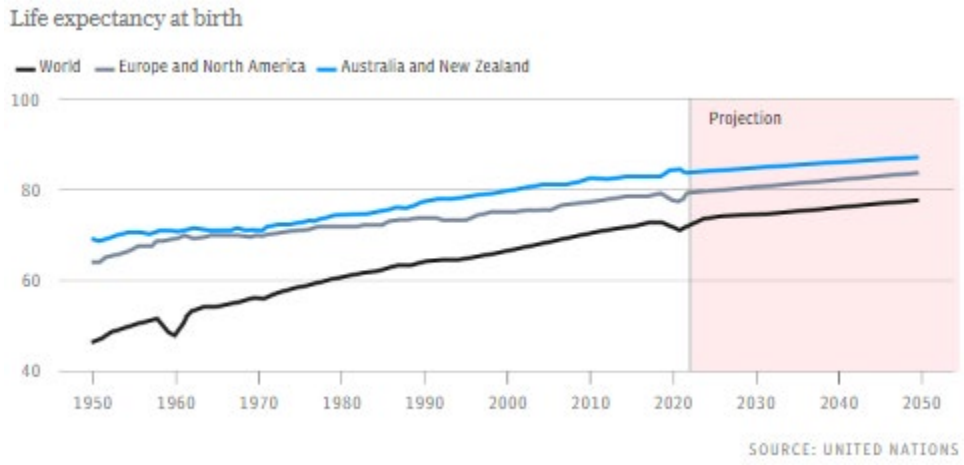



[826] https://www.oecd.org/social/declining-fertility-rates-put-prosperity-of-future-generations-at-risk.htm; https://www.oecd.org/publication/society-at-a-glance/2024/

Figure 7 shows that global population growth has been on a downward trend since the mid-1960s from 2% to around 1% currently and is projected to be 0.5% by 2050. This is due mainly to the decline in fertility. The increase in deaths in 2020-21 caused by Covid-19 is also visible in the figure.

Figure 8 shows that, while life expectancy is expected to increase, the rate of increase is expected to slow down a little. By 2050, the global population aged 60 and over is projected to exceed the population under 15. The global population – which reached 7bn in 2011 and 8bn on 15 November 2022 – is now expected to peak at 10.3bn in the mid-2080s rather than in the 22nd Century as previously predicted.[827] In October 2024, the UK Office for National Statistics reported that fewer people were living to 100. Paul Farmer, Age UK chief executive, said: 'We know that over the last couple of years or so overall life expectancy is starting to flatten out. That's partly driven by Covid but also a whole range of other health and health inequality issues. In a sense, it's not surprising that the numbers of centenarians are not increasing'.[828]

**Figure 8: The increase in life expectancy is expected to slow**




In July 2022, the International Longevity Centre (UK) released five reports on aging in Australia, China, Japan, Indonesia and South Korea. The main findings were:

- Japan's population is aging rapidly. In 2017, 40% of Japan's workers were over 50 – predicted to rise to 47% by 2035. In 2022, Japan recorded the lowest number of births (799,728, a fertility rate of 1.3) and the highest number of deaths (1.58m) since the Second World War.[829] By 2024, 36.25m Japanese were aged over 65, that

[827] https://www.pensionpolicyinternational.com/world-population-projected-to-peak-at-10-3-billion-in-2080s-new-united-nations-report-says/
[828] https://www.telegraph.co.uk/business/2024/10/01/number-people-living-to-100-declines-first-time-since-covid/
[829] https://www.pensionpolicyinternational.com/japan-births-fall-to-record-low-as-population-crisis-deepens/

is 29.3% of the population, the highest proportion of any country – and this could reach 34.8% by 2040.[830] At the same time, the total labor force is projected to fall from 69.3m in 2023 to 49.1 million in 2050. Already in 2024, 51% of companies feel there is a shortage of full-time employees.[831]

- Over 50s made up 29% of Australia's workforce in 2017 – rising to 35% by 2035. Over 2 in 5 of Australian dollars were spent by older households in 2015, around 18% of GDP.
- By 2035, 42% of China's population will be over 50. In China, people over 65 spent 5 more hours a year volunteering than people at other ages.
- In 2018, 37% of South Korea's population was over 50 and by 2035, 51% of people will be over 50. By 2035, more than 6 in 10 South Korean employees could be aged 50 and over.[832]
- In Indonesia in 2018, 72% of people aged 50-64 were in employment and a quarter of Indonesia's population was over 50 – this is set to increase to 28% by 2035.[833]

In May 2021, China announced it was ending its policy of limiting couples to two children and would now allow them to have three.[834] The government said the problem of an aging population was deepening and the change would help to improve the structure of China's population and maintain its advantage in human resources.[835] The Chinese population aged over 65 exceeded 14% of the total population in 2021.[836] China's population fell by 850,000 in 2022 and by 2.08 million in 2023 to 1.409bn.[837] The fertility rate is close to 1.0. President Xi Jinping wants to 'actively cultivate a new culture of marriage and

---

[830] *OECD Employment Outlook 2025* predicts that Japan's old age dependency ratio will rise to 82% by 2060; https://www.pensionpolicyinternational.com/the-world-is-ageing-what-are-the-macroeconomic-implications/

[831] https://www.pensionpolicyinternational.com/japan-faces-labor-shortages-and-demographic-crisis-as-elderly-population-hits-record-high/

[832] *OECD Employment Outlook 2025* predicts that South Korea's old age dependency ratio will rise to 96% by 2060; https://www.pensionpolicyinternational.com/the-world-is-ageing-what-are-the-macroeconomic-implications/. According to Randall Jones from the Korea Economic Institute, 'kindergartens are being turned into nursing homes and wedding halls into funeral parlours'; https://www.ft.com/content/152766ba-072d-4f5d-948e-d60f93e406d1

[833] India, by contrast, lies at the younger end of the demographic spectrum. With a significantly lower median age of 29.8 years (compared with 50.8 in Japan, 40.2 in China and 39.2 in the US), India's working-age population share is expected to remain high for decades. This will yield a 'demographic dividend' for some time as the younger population supports higher consumption, investment, innovation and overall productivity; https://www.pensionpolicyinternational.com/the-world-is-ageing-what-are-the-macroeconomic-implications/

[834] China introduced a one-child policy in 1979 and a two-child policy in 2016.

[835] https://www.pensionpolicyinternational.com/china-introduces-three-child-policy-to-alleviate-problem-of-ageing-population/

[836] https://www.pensionpolicyinternational.com/china-may-see-negative-population-growth-in-2022-12-years-earlier-than-un-prediction-experts/

[837] The United Nations *World Population Prospects 2024* report predicts that China's 1.4bn people could shrink substantially by the end of the century: 'It is anticipated that China, the country currently with the world's second largest population, will likely experience the largest absolute population loss between 2024 and 2054 (204 million), followed by Japan and the Russian Federation (21 and 10 million, respectively)'; https://www.pensionpolicyinternational.com/the-world-is-ageing-what-are-the-macroeconomic-implications/

childbearing'. In 2022, 17 government departments released guidelines on supporting policies in finance, tax, housing, employment, and education 'to create a fertility-friendly society and encourage families to have more children'.[838] Jilin province in northeast China is offering up to 200,000 yuan ($31,400) in 'marriage and birth consumer loans' to married couples to promote population growth; it has one of the fastest-shrinking populations in China.[839] In 2024, China introduced a new birth subsidy scheme: women receive a 6,500-yuan (US$897) reward for having two children and an additional allowance of 800-yuan a month until a new baby reaches three years.[840]

However, University of Michigan demographer Zhou Yun points out that fertility decline is often very difficult to reverse and no country with a fertility rate that has fallen below the 2.1 replacement rate has ever managed to raise it above the replacement rate again.[841]

The ILC(UK) reports, while highlighting the global nature of population aging, also emphasize the crucial role of older workers and consumers for post-pandemic recovery in these and other countries – which it calls the 'global longevity dividend'.[842]

The world is also trying to cope with supply shortages, insufficient workers and the financial burden of the rising proportion of pensioners – which will all worsen as the global population switches from boom to bust.

The UN predicts that in Italy, the population will fall from 59m to 55.3m by 2040, while Germany's population will fall over the same period from 83.4m to 81.2m. Holger Schmieding, an economist at Berenberg Bank, says Germany can do more to get people to join the workforce. Also 'There is room to increase the retirement age - it is going up to 67 already, it probably has to go up further'. Germany is also attractive to migrants which helps companies to keep growing despite the low domestic birth rate.[843]

The US Census Bureau projects that the US population will begin to decline by 2080, resulting in substantial risks for economic and social stability. Fewer young people are having children, so the population ages and there are more retired relative to working-age people. The proportion of Americans over the age of 65 was 9% in 1960, 17% in 2021, and is predicted to be 29% in 2100. As a result, companies will struggle to find workers – the Congressional Budget Office predicts that the size of the US labor force will grow by only 0.2% a year between 2024 and 2031– and Social Security, Medicare and Medicaid

[838] https://www.pensionpolicyinternational.com/chinas-population-drops-by-2-million-in-2023-due-to-record-low-birth-rate/
[839] https://www.pensionpolicyinternational.com/chinese-province-offers-31000-baby-loans-to-counter-shrinking-population/
[840] https://www.pensionpolicyinternational.com/why-china-is-betting-on-birth-subsidies-to-solve-its-population-crisis/
[841] https://www.pensionpolicyinternational.com/chinas-population-drops-by-2-million-in-2023-due-to-record-low-birth-rate/
[842] https://ilcuk.org.uk/global-longevity-dividend/
[843] https://www.telegraph.co.uk/business/2022/07/13/europe-faces-ageing-population-nightmare-absolute-collapse

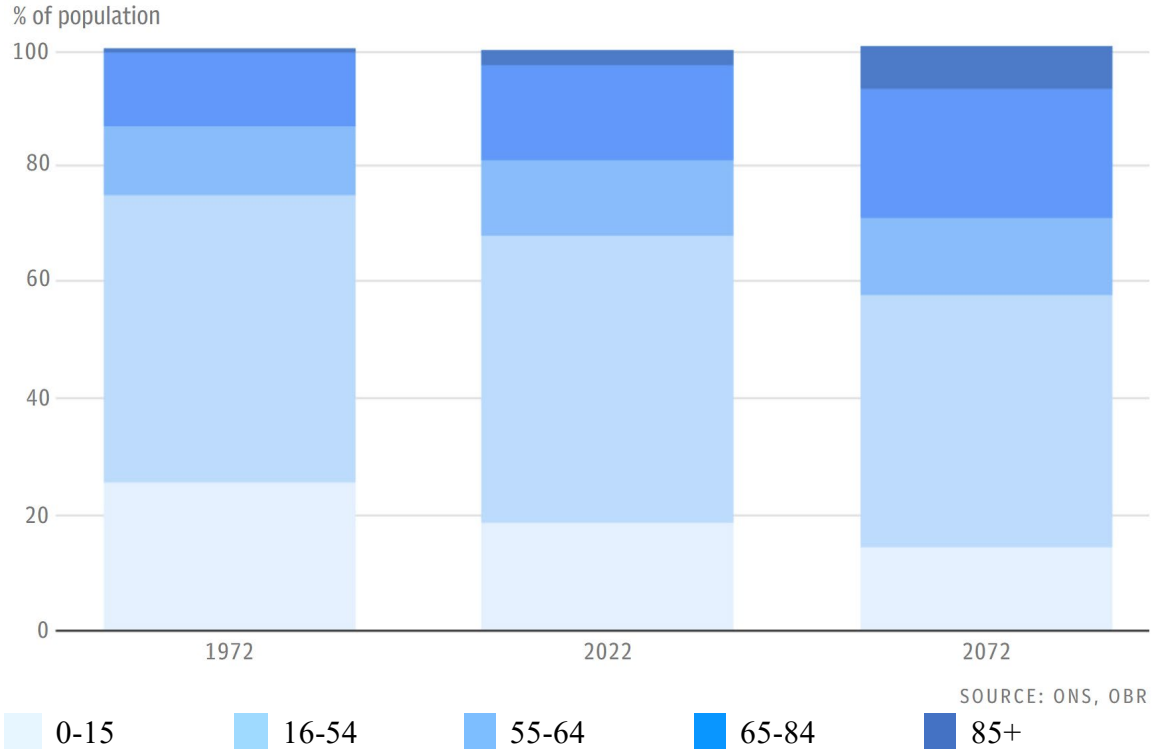
programs will become unsustainable. While immigration can help to ease the problem, the natural population decline (population growth without immigration) may be too great. One of the explanations for having fewer children is cost, estimated at around $240,000 over the first 18 years by LendingTree. Another is the preference for younger people (millennials and Gen-Z) to spend their money on leisure for themselves, such as travel, instead of saving for a future family. A 2021 study from the Pew Research Center found that 44% of young non-parents said they are unlikely to have children. A 2022 Harris Poll survey for Fortune found that 65% of non-parents agreed that the freedom that comes with not having children brings them happiness. While sectors of the economy favoured by younger consumers – travel, transport, retail, clothes and entertainment – could benefit, other sectors which are typically associated with higher productivity – such as IT, medicine and legal – or with supply chain security – such certain types of manufacturing – could face challenges attracting young talented staff. Companies in these sectors will have to respond by offering more attractive benefits, such as remote flexibility, professional development opportunities, and student loan assistance. These companies will also need to make greater use of automation. Japan has led the way here by using industrial robots in its manufacturing and later life service sectors. Artificial intelligence applications, such as ChatGPT, will also help boost productivity.[844] Immigration could also alleviate labor shortages in certain sectors – such as agriculture, construction, leisure, hospitality and manufacturing – but since it has been the largest contributor to US population growth for decades, it would need to be significantly scaled-up to impact current population projections. However, countries that have traditionally supplied large numbers of immigrants to the US, namely China and India, are experiencing their own slowdowns in population growth.[845, 846]

The UN predicts that, by 2050, the best-balanced work forces will be in South and Southeast Asia, Africa and the Middle East, potentially reshaping economic growth and geopolitical power balances. This will give these regions a 'demographic dividend', as a growing share of workers compared to dependants promotes economic growth.[847] By contrast, much of the Western world could turn into what Professor Pieter Vanhuysse of the University of Southern Denmark calls 'gerontonomias', economies that have lost their former dynamism leading to 'secular stagnation and the increase of gerontocracies, or elderly oriented democracies'.[848]

[844] AI and robotics are discussed in more detail below.
[845] https://www.pensionpolicyinternational.com/anticipated-u-s-population-decline-and-the-risks-ahead/
[846] Some commentators predict the end of the human race within the next 10,000 years. According to Henry Gee, 'The human population will sink to a level that is ultimately unsustainable, and extinction will beckon'. To put this into perspective, hominins (bipedal apes) date back two million years ago, while homo sapiens date back 300,000 years ago. See Henry Gee (2025) *The Decline and Fall of the Human Empire*, Picador; https://www.panmacmillan.com/authors/henry-gee/the-decline-and-fall-of-the-human-empire/9781035030835
[847] Lauren Leatherby (2023) How a vast demographic risk will reshape the world, New York Times, 16 July; https://www.nytimes.com/interactive/2023/07/16/world/world-demographics.html
[848] https://www.ft.com/content/152766ba-072d-4f5d-948e-d60f93e406d1

Figure 9 shows the UK's population age structure according to calculations made by the Office for Budget Responsibility (OBR). In 1972, 60% of the population was aged between 16 and 64 and this rose to 62.2% in 2022, due to the large number of baby boomers who joined the workforce. Once they retire, the working age population will fall to 56.4% by 2072. By then, almost 30% of the British population will be over 65, more than double the proportion in 1972. The OBR predicts that age-related state spending will rise from 27% of GDP in 2023 to 36.1% in 2071. State pensions will rise from 4.8% to 8.1% of GDP or from £110bn[849] in 2022 to £185bn in 2023 prices.

**Figure 9: Population age structure in the UK**




Source: https://www.telegraph.co.uk/business/2022/12/03/why-state-pension-age-may-never-reach-70/

This rising cost could be ameliorated by increasing the state pension age. In 2018, the UK state pension age was increased to 66 and is set to rise to 67 by 2028 and to 68 by 2046. The government is considering bringing this forward to 2039. Each year that the pension is not paid saves £10bn and, in addition, people pay in-work taxes for another year. The Institute for Fiscal Studies found the rise in state pension age from 65 to 66 resulted in 25,000 men and 30,000 women aged 65 working for an extra year.

However, John Cridland, who chaired the UK's first state pension age review in 2017, while accepting that the implications for the public finances is 'really concerning', argues that there could be an upper limit to the state pension age: 'while the government may be able to justify bringing forward an increase to 68, telling people to work until they're 69 or

[849] https://obr.uk/forecasts-in-depth/tax-by-tax-spend-by-spend/welfare-spending-pensioner-benefits/

even 70 is a much more difficult prospect. The UK has got a lot of people who started work at 16. Many do manual work in hard physical jobs, and expecting them to wait till the age of 70 for a pension is not a reasonable balance. One might need to increase the state pension age beyond 68 in years to come, but I'm talking decades, and only if longevity increases take off again. There has to be a reasonable balance to deliver intergenerational fairness. [Further,] it's not obvious that the working population will have as much healthy life expectancy because of multiple morbidity, where more people suffer from multiple conditions like dementia, obesity, diabetes, that can actually affect the quality of people's lives'. His report recommended that those with poor health or caring responsibilities should be able to access the state pension at 67.[850] This suggests that there could be limits to the longevity dividend identified by the ILC(UK).

Despite this, in February 2024, ILC(UK) released a report which argued that the UK's population was aging so quickly that the state pension age would need to rise to 70 or 71 to maintain the status quo of a constant number of workers per state pensioner – and this could be as early as 2040. While the report accepted that life expectancy increases had paused during the austerity years following the Global Finance Crisis and that Covid-19 had temporarily eased the pressure for increases in state pension age after 2027, it warned that longer-term the pressure will be to increase it. This is because of the fact that many workers are facing long-term ill health earlier in life and that their exit from the workforce before they reach state pension age reduces the tax base to pay for pensions. In addition, a smaller working population and a larger economically inactive population create huge labour shortages that lead to additional funding problems, such as increased welfare benefits. Nevertheless, the report accepted that there were challenges in raising the retirement age to such a high level, since only 50% of adults are disability-free and able to work by age 70. The report concluded 'Our research … suggests a greater focus is needed on preventing ill-health not just in old age but from early age through adulthood. Policymakers can no longer ignore the impact of poor health on wider society and doing so will simply make wider policies related to work or pensions ineffective'.[851]

Another aspect of population aging is the differential impact on the rich and poor, i.e., health inequalities due to differences in wealth. A 2020 study by the Longevity Science Panel in the UK found that, while life expectancy had increased for all socio-economic groups between 2001 and 2015, it increased most for the richest cohort. The difference in life expectancy between rich and poor was 7.2 years in 2001, but this had increased to 8.4 years in 2015[852] and to 9 years in 2020.[853] Another study found that, while socio-economic status affects the incidence of multimorbidity (two or more of diabetes, coronary heart disease, stroke, chronic obstructive pulmonary disease (COPD), depression, arthritis,

[850] Szu Ping Chan (2022) Why the state pension age may never again reach 70, *Daily Telegraph*, 3 December; https://www.telegraph.co.uk/business/2022/12/03/why-state-pension-age-may-never-reach-70
[851] https://www.pensionpolicyinternational.com/uks-ageing-population-prompts-calls-to-push-state-pension-age-up-to-71/
[852] Life expectancy gap between rich and poor widens, *BBC News*, 15 February 2018.
[853] Amelia Hill (2020) Being wealthy adds nine years to life expectancy, says study, *Guardian*, 15 January. The same 9-year difference holds in the US. The UK results come from the English Longitudinal Study of Ageing, while the US results come from the US Health and Retirement Study.

cancer, dementia, and Parkinson's disease), it did not affect the risk of mortality after the onset of these adverse health conditions, implying that primary prevention is key to reducing social inequalities in mortality (Dugravot et al (2019)). This is confirmed by a report written by the UK All-Party Parliamentary Group (APPG) for Longevity (*The Health of the Nation: A Strategy for Healthier Longer Lives*) which estimated that up to 75% of new cases of heart disease, stroke and type-2 diabetes, and 40% of cancer incidence and dementia risks could be reduced if individuals cut down on smoking and alcohol, increased physical activity and changed to a healthy diet. The report also found that a key reason for low productivity in certain parts of the country (e.g., the north of England) is that health is worse and reducing the health gap would keep people in work longer and hence increase national output.[854]

These findings will have implications for fairness between different cohorts of the same generation, for example, when governments raise the retirement age for all in line with increasing average life expectancy. In response to these inequalities, the UK government set up the UK Longevity Council to advise it on how best to use innovations in technology products and services to improve the lives of the older population. With the number of people in the UK over the age 65 to double to more than 20 million over the next half century, the government has set itself the Aging Society Grand Challenge which aims to ensure that people in the UK enjoy an extra 5 years of healthy and independent living by 2035, while narrowing the gap between the experience of the richest and poorest.[855]

Similar initiatives are happening in other parts of the world. For example, the Stanford Center on Longevity (SCL), recognizing that half of 5-year-olds in the US are likely to reach the age of 100, has a mission to ensure these 'century-long lives are healthy and rewarding'. It has developed a New Map of Life[856] that seeks to change social institutions, norms and policies that evolved when lives were only half as long, for example, the idea that people will retire and live off their savings at age 65. The SCL envisions a 'future in which all people, regardless of socio-economic status, can make the most of the advantages afforded by increased lifespan—resulting in lives infused at every stage with a sense of belonging, purpose, and worth. We can meet challenges that longevity creates, and make the most of the 100-year opportunity if we act now, guided by these principles:

- Make use of age diversity
- Create longevity-ready communities
- Align health spans to life spans
- Build financial security from the start
- Invest in future centenarians to deliver big returns
- Support life transitions
- Learn throughout life
- Work more years, with greater flexibility

[854] Amelia Hill (2020) Health inequality greater than previously thought, report finds, *Guardian*, 12 February.
[855] https://www.gov.uk/government/news/experts-to-help-uk-champion-ageing-society-opportunities
[856] https://longevity.stanford.edu/the-new-map-of-life-initiative/

- Harness scientific and technological breakthroughs to transform the future of aging
- Ensure that advances are distributed to the entire population'.

In June 2025, a UN study reported that economic strains, including job insecurity, were among the biggest barriers to parenthood, with around 20% of people in 14 countries surveyed not expecting to have the number of children they desired. Natalia Kanem, executive director at the United Nations Population Fund, said: 'Fertility rates are falling, in large part because many feel unable to create the families they want, and that is the real crisis. Prohibitive costs of raising children, job insecurity, housing, the lack of a suitable partner and sexism were all obstacles to parenthood. …The answer lies in responding to what people say they need: paid family leave, affordable fertility care, and supportive partners'. Fertility rates have fallen below 2.1 births per woman in over half of all countries, the threshold needed for population stability without immigration.[857] In 2025, the birth rates were 1.4 in the UK (the lowest on record) and 0.72 in South Korea (the lowest in the world).[858]

The World Economic Forum's (WEF) *Global Risks Report 2025* predicts that a first pillar pension crisis 'will start to bite' over the next decade in super-ageing societies – where over 20% of a country's population is over 65 years old – such as Japan, Italy and Germany. Globally, the number of people aged 65 and older is expected to increase by 36% from 857mn in 2025 to 1.2bn in 2035. The report said: 'Over the next decade the pensions crises and their implications will start hitting home in super-ageing societies, as it becomes clear that current state pension systems were designed for a much younger demographic with fewer years of retirement that needed funding'.

The second pillar will also struggle because many countries are moving away from DB systems to DC systems: 'For many people, this can be challenging as they may have insufficient income, lack the requisite financial understanding, or fail to make good early decisions about savings and retirement. As dependency ratios rise, fewer people will be contributing to employer and private pensions schemes relative to the number of people whose retirements need funding, and with the length of those retirements rising. …Pension shortfalls will also disproportionately affect lower-income workers who have not managed to make significant savings during their careers, even if they have been fully employed. In the EU, for example, already today one in five elderly people face the risk of poverty or social exclusion and this figure is set to rise by 2035. …Women on average have significantly higher pensions gaps than men given time taken out of formal employment over the course of their careers to care for children or elderly relatives, as well as their lower average pay compared to men. In the EU, women's pensions are nearly 30% lower than those of men, meaning that they are at a 35% higher risk of poverty'.

The WEF argues that this could lead to institutional pension funds seeking to increase their returns by allocating higher proportions of their assets to riskier investments, such as crypto

[857] https://www.ft.com/content/1559b9df-0f76-4c50-baa4-32242d2fdea0
[858] https://www.telegraph.co.uk/business/2025/08/27/fertility-rate-drops-to-record-low

assets and private credit: 'These riskier investments will not always pay off, and over time this could worsen the already suboptimal funding ratios of some of these institutions. If there are extended periods of market underperformance, this could lead to many more individuals facing shortfalls in funding their retirement'. An alternative is for countries with super-ageing populations to raise the statutory retirement age. But the WEF warns that attempts to do this face resistance from voters, a rising proportion of whom are themselves close to retirement: 'This segment of the population tends to have high voter turnout, making it increasingly likely that policy outcomes will be in their favour. Intergenerational tensions could become an ongoing feature of super-ageing societies, with discontented younger working cohorts resenting being called upon to pay more towards funding retiree pensions. … This illustrates the complexity of aligning key stakeholder interests behind pension reform'.[859]

In January 2026, the EU's Directorate-General for Economic and Financial Affairs published a report entitled *The Impact of Ageing on the Fiscal Sustainability of EU Health Care Systems*.[860] It noted that the EU's *2024 Ageing Report* predicted that population ageing would pose a major threat to EU health care fiscal sustainability, with public spending projected to rise by 4% to 20% by 2070 due to increased demand for care and a shrinking, over-65 dependency ratio. This shift reduces the tax base while boosting costs, threatening to create significant funding gaps. The *2024 Ageing Report* suggested that up to a third of the projected increase in health expenditure will occur within the next decade. Without reforms, the EU health care system is unsustainable. The report recommended the following policy responses and mitigations: structural reforms – to enhance sustainability, EU countries are advised to implement reforms focused on strengthening primary care, improving hospital efficiency, and using cost-effective purchasing; targeted investment in health promotion and disease prevention to reduce the long-term burden; digital transformation – the use of digital health tools and AI to improve efficiency in health systems; and EU support – the European Semester and the Recovery and Resilience Facility to provide financial support and a framework for these reforms. Despite the challenges, the report was positive about the long-term outlook: by 2040, more than 1 in 4 people in the EU will be aged 65 or older, intensifying the need for sustainable, long-term health system funding. While the impact is significant, it is considered manageable through proactive policy actions and structural adjustments.

Some of these issues – longer working lives, higher state pension ages, and narrowing the life expectancy gap – will clearly have consequences for the pricing of future PRT deals.

[859] https://www.pensionpolicyinternational.com/pension-crises-will-start-to-bite-over-next-decade-wef-risk-report-finds/

[860] https://economy-finance.ec.europa.eu/publications/impact-ageing-fiscal-sustainability-eu-health-care-systems-projections-and-policy-responses_en

### *The aging process and anti-aging treatments*

Life expectancy is strongly linked to the aging process.[861] Aging results in a progressive deterioration in physiological integrity, leading to impaired function and increased vulnerability to death. This deterioration is the primary risk factor for neurodegenerative diseases, cancer, diabetes, and cardiovascular disorders. López-Otín et al. (2013) show that there are nine candidate hallmarks of aging:[862] genomic instability,[863] telomere attrition,[864] epigenetic alterations,[865] loss of proteostasis,[866] deregulated nutrient sensing,[867]

[861] See, e.g., Andrew Steele (2020) *The New Science of Getting Older Without Getting Old*, Bloomsbury, London; https://www.bloomsbury.com/uk/ageless-9781526608277/

[862] Carlos López-Otín, Maria A. Blasco, Linda Partridge, Manuel Serrano, and Guido Kroemer (2013) The Hallmarks of Aging, *Cell*, 153(6):1194-1217; https://doi.org/10.1016/j.cell.2013.05.039

[863] A high frequency of mutations within a cell's genome.

[864] The telomere ends of chromosomes get shorter as cells divide and eventually become too short for cells to divide further. Shortened telomeres are associated with aging cells that are senescent.

[865] Epigenetics is the study of how your behaviours and environment can cause changes that affect the way your genes work. Unlike genetic changes, epigenetic changes are reversible and do not change your DNA sequence, but they can change how your body reads a DNA sequence; https://www.cdc.gov/genomics/disease/epigenetics.htm

[866] Proteostasis is a balanced state in which the body's production of proteins is stable and without defects. Proteins are molecules that do most of the work in cells and are needed for the structure, function, and regulation of the body's tissues and organs. They are composed of amino acids and are categorised according to their function: antibody, enzyme (carries out most of the chemical reactions that take place in cells), messenger (transmits signals to coordinate biological processes between different cells, tissues, and organs), structural component, and transport/storage. A loss of proteostasis is associated with the production of excess, insufficient or misshapen proteins that send incorrect signals. See: Steve Hill (2018) Hallmarks of Aging: Loss of Proteostasis, 23 May; https://www.lifespan.io/news/hallmarks-of-aging-loss-of-proteostasis/

[867] Metabolism is the balance between anabolism (building up body tissues and energy stores) and catabolism (breaking down body tissues and energy stores to get fuel for body functions). The body has multiple nutrient sensing pathways to ensure that it takes in the right amount of nutrition – not too much, not too little. Excess metabolic activity, e.g., anabolic signalling, together with changes in nutrient availability and composition, damage cells and cause them to age faster. These damaging events also deregulate the nutrient-sensing molecules and downstream pathways, for example, signalling greater food intake when the body does not need it. Age-related obesity, diabetes and other metabolic syndromes result. Decreased nutrient signalling, achieved with caloric restricted diets or by stimulation of proteins called sirtuins, promotes healthspan and longevity. See: Deregulated Nutrient Sensing; https://www.merckmillipore.com/GB/en/life-science-research/genomic-analysis/Epigenetics-and-Nuclear-Function/Deregulated-Nutrient-Sensing/FsCb.qB.u04AAAFQ6t52i0ib,nav

mitochondrial dysfunction,[868] cellular senescence,[869] stem cell exhaustion,[870] and altered intercellular communication.[871]

López-Otín et al. (op cit) continue: 'Aging research has experienced an unprecedented advance over recent years, particularly with the discovery that the rate of aging is controlled, at least to some extent, by genetic pathways and biochemical processes conserved in evolution. … A major challenge is to dissect the interconnectedness between the candidate hallmarks and their relative contributions to aging, with the final goal of identifying pharmaceutical targets to improve human health during aging, with minimal side effects'.

Dr Eric Verdin, president and CEO of the Buck Institute for Research on Aging[872] explains the origins of aging research: 'The initial discoveries by several groups between 1985 and 1995 suggested that there are genes that can mitigate the aging process. If these genes are mutated to either gain or lose function, one can dramatically impact healthspan and lifespan. …We've learned a number of key lessons. Firstly, we've learned that there are genetic pathways that interact together and appear to control aging. Secondly, these pathways seem to be conserved across different species. So, we find the same pathways in yeast, in worms and in humans. Thirdly, we can speak to these pathways via small molecule drugs to have the same effect as mutating the gene, and subsequently impacting the aging process. Finally, these genes that control aging don't just control lifespan, they also control healthspan'.[873]

---

[868] Mitochondria are organelles – specialized subunits within cells with a specific function – found in most cells, in which the biochemical processes of respiration and energy production occur. Mitochondrial dysfunction occurs when the mitochondria do not work as they should due to damage, mutation or conditions such as progressive inefficiency of electron transport chain complexes resulting from destabilization or oxidative stress owing to excessive production of reactive oxygen species (ROS). This can affect other diseases, such as Alzheimer's, diabetes and cancer. See: Joshua N. Farr and Maria Almeida (2018) The Spectrum of Fundamental Basic Science Discoveries Contributing to Organismal Aging, *J Bone Miner Res*, 33(9): 1568–1584; doi: 10.1002/jbmr.3564

[869] Irreversible cell cycle arrest driven by a variety of mechanisms, including telomere shortening, other forms of genotoxic stress, or mitogens or inflammatory cytokine. Senescent cells have stopped dividing and hence renewing themselves and so have lost their purpose, but can nevertheless destabilize neighbouring cells and promote inflammation. See: Edward J. Masoro and Steven N. Austad (eds) *Handbook of the Biology of Aging* (seventh edition, 2011); https://www.sciencedirect.com/book/9780123786388/handbook-of-the-biology-of-aging

[870] A reduction in stem cell activity which can lead to diseases and other issues, such as immunosuppression through reduced production of bacteria-killing and virus-killing white blood cells, muscle loss, frailty, and the weakening of bones. See: Patrick Deane (2018) Hallmarks of Aging: Stem Cell Exhaustion, 18 September; https://www.lifespan.io/news/hallmarks-of-aging-stem-cell-exhaustion/

[871] Cells, as they age, show an increase in self-preserving signals that result in damage elsewhere. Altered intercellular communication with aging contributes to a decline in tissue health. In particular, senescent cells trigger chronic inflammation that can further damage aging tissues. See: Altered Intercellular Communication; https://www.merckmillipore.com/GB/en/life-science-research/antibodies-assays/antibodies-overview/Research-Areas/cell-signaling/Altered-Intercellular-Communication/C.qb.qB.O48AAAFQe592i0hr,nav

[872] https://www.buckinstitute.org/

[873] Interview in *Longevity Trends 2020*, published by Longevity Leaders, January 2020.

There have been a number of significant positive innovations that help to identify and treat noncommunicable diseases associated with aging, such as dementia and cancer. These can be classified as gerotheraputics.[874] Examples include:

- Professor Steve Horvath (UCLA) and Ken Raj (Public Health England) have demonstrated that rapamycin[875] retards the epigenetic aging of human cells – using an epigenetic clock (called the Skin and Blood Clock) which is an accurate biomarker for aging that relies on the mathematical precision of the relationship between chemical modifications on DNA called methylation and changes in age[876]
- The finding that rapamycin, administered to middle aged mice, increased survival significantly in both male and female mice.[877]
- The discovery that mTOR (mechanistic target of rapamycin) has a role in influencing cell growth and proliferation, and, in the case of deregulated[878] cell proliferation, can cause diseases such as cancer and neurodegeneration. Inhibiting mTOR slows cell growth, increases recycling, and enhances cell efficiency. A number of mTOR inhibitors have been developed to treat these diseases, including sirolimus, everolimus, and temsirolimus.[879]
- Dysregulated[880] nutrient sensing is also involved in the management of aging and builds on the fact that mTOR also acts as a cellular fuel gauge, sensing when nutrients are plentiful and instructing the cells to grow and divide. But when the system is switched on for too long, which can happen with aging, it can lead to cellular wear and tear. By dialling down the system using an mTOR inhibitor like rapamycin, researchers have shown that the aging process can be slowed. For example, Mannick et al. (2018) used this treatment on a group of elderly people and then gave them a flu vaccination which does not tend to be effective in older people because their immune systems are senescent; however, the infection rate over the course of a year was 50% of that of the control group.[881]

---

[874] Gerotherapeutics enhance resilience mechanisms that counter age-related molecular damage to prevent chronic diseases, frailty, and disability, thereby extending healthspan; https://pubmed.ncbi.nlm.nih.gov/37389519/

[875] A bacterial antifungal compound discovered in the soil of Easter Island in the 1970s. It is also an immunosuppressant used in organ transplants.

[876] http://mypharmacynews.com/health-problems/rapamycin-retards-epigenetic-ageing-of-keratinocytes/

[877] Randy Strong, Richard A. Miller, Molly Bogue, Elizabeth Fernandez, Martin A. Javors, Sergiy Libert, Paul Anthony Marinez, Michael P. Murphy, Nicolas Musi, James F. Nelson, Michael Petrascheck, Peter Reifsnyder, Arlan Richardson, Adam B. Salmon, Francesca Macchiarini, and David E. Harrison (2020) Rapamycin-mediated mouse lifespan extension: Late-life dosage regimes with sex-specific effects, *Aging Cell*. 2020;00:e13269. https://doi.org/10.1111/acel.13269

[878] Deregulated means the regulatory mechanism is not functioning.

[879] https://pmc.ncbi.nlm.nih.gov/articles/PMC4849280/; https://www.uptodate.com/contents/pharmacology-of-mammalian-mechanistic-target-of-rapamycin-mtor-inhibitors

[880] Dysregulated means the regulatory mechanism is functioning in the wrong way.

[881] https://liferisk.news/is-a-geroscience-breakthrough-the-black-swan-event-for-life-insurers-and-pensions/; Joan B. Mannick, Melody Morris, Hans-Ulrich P. Hockey, Guglielmo Roma, Martin Beibel, Kenneth Kulmatycki, Mollie Watkins, Tea Shavlakadze, Weihua Zhou, Dean Quinn, David J Glass, and Lloyd B Klickstein (2018) 'TORC1 inhibition enhances immune function and reduces infections in the elderly', *Sci Transl Med*, 11;10(449):eaaq1564; doi: 10.1126/scitranslmed.aaq1564.

- Potential reversal of aging using a younger person's blood, following successful experiments with mice.[882]
- Professor Tony Wyss-Coray (Stanford) has identified circulating factors in plasma that can rejuvenate or restore function in the aging brain, leading to the development of anti-aging therapies based on the plasma proteome, suitable for treating age-related macular degeneration and neurodegenerative disorders.[883]
- Development of inhibitors for the protein[884] complex TORC1 which extend lifespan and healthspan by, for example, reducing the incidence of respiratory tract infections or treating neurodegenerative diseases by inducing autophagy, a process which by which cells clear out toxic protein aggregates.[885]
- Scientists have converted the cells of a deceased 114-year-old into young pluripotent stem cells, thereby reversing the telomere aging clock in a supercentenarian's cells and providing support for the hypothesis of no upper age limit for reprogramming cellular aging.[886]
- Identification of an inflammatory marker called sCD14 which is linked to cognitive decline and dementia, allowing early intervention.[887]
- A new protein blood test that can predict future cognitive decline.[888]
- Randall J. Bateman (Washington University School of Medicine in St. Louis) has developed a simple blood test that can detect Alzheimer's disease in its earliest stages by measuring levels of the protein amyloid beta which begin to collect in the brain 15 to 20 years before symptoms arise and play a key role in the development of Alzheimer's.[889] Researchers from the University of Gothenburg have developed a cheap test that measures the level of the p-tau217 protein in the blood.[890] Researchers from Aarhus University have developed a blood test to spot Alzheimer's before progression to dementia.[891] Veravas Inc. (Austin, TX, USA) has

[882] Undulating changes in human plasma proteome profiles across the lifespan, *Nature Medicine*, 5 December 2019.
[883] Steven Braithwaite, Chief Scientific Officer, Alkahest, interviewed in *Longevity Trends 2020*, published by Longevity Leaders, January 2020.
[884] Proteins are the foundation of life.
[885] Joan Mannick, Chief Medical Officer, resTORbio, interviewed in *Longevity Trends 2020*, published by Longevity Leaders, January 2020.
[886] Phil Newman (2020) 114 year-old cells converted to pluripotent stem cells, *Longevity Technology*, 28 February; https://www.longevity.technology/114-year-old-cells-converted-to-pluripotent-stem-cells.See also: Old human cells rejuvenated with stem cell technology, *Science News*, 24 March 2020.
[887] Inflammatory marker linked to dementia, *EurakAlert! Science News*, 9 December 2019.
[888] https://www.labmedica.com/molecular-diagnostics/articles/294805450/protein-blood-test-could-predict-future-cognitive-decline.html
[889] https://medicine.wustl.edu/news/bateman-receives-potamkin-award-for-alzheimers-research/; https://www.labmedica.com/clinical-chem./articles/294789678/blood-based-biomarker-predicts-onset-of-symptomatic-alzheimers-disease.html; https://www.labmedica.com/hematology/articles/294792023/unique-diagnostic-test-based-on-mass-spectrometry-technique-accurately-identifies-early-stage-alzheimers-disease.html; https://www.labmedica.com/molecular-diagnostics/articles/294793970/blood-test-could-detect-alzheimers-up-to-17-years-in-advance.html
[890] https://www.telegraph.co.uk/news/2024/01/22/alzheimers-blood-test-revolution-for-over-50s-dementia
[891] https://www.labmedica.com/molecular-diagnostics/articles/294801080/advanced-blood-test-to-spot-alzheimers-before-progression-to-dementia.html

developed a blood-based test – the VeraBIND Tau Assay – which measures a key Alzheimer's biomarker – the pathological binding activity between hyperphosphorylated tau and normal tau – in asymptomatic and symptomatic individuals and detects the active spread of tau proteins and hence provides a more direct indication of disease progression.[892]

- The development of protein-destroying drugs, capable of degrading the MYC cancer-fuelling protein or the tau protein responsible for Alzheimer's.[893]
- The identification of two natural compounds – CMS121 and J147 – that can reverse age-related cognitive impairment and potentially treat Alzheimer's by restoring mitochondrial function, such as cell respiration and energy production, in the aging brain.[894]
- The identification of the E3 and E4 variants of the APOE gene as being the potential cause of 90% of Alzheimer's disease cases. Dr Dylan Williams, lead investigator of the research which was conducted at University College London, said: 'We have long underestimated how much the APOE gene contributes to the burden of Alzheimer's disease'.[895]
- The discovery that higher levels of humanin, a peptide[896] encoded in the small genome of mitochondria, are associated with longer lifespans, better health, and a lower risk for diseases such as Alzheimer's.[897]
- The development of an antibody that stimulates microglia, the brain's immune cells, in such a way that they live longer, divide more quickly and detect aberrant substances more easily, thus helping to prevent the progression of Alzheimer's.[898]
- The discovery that Alzheimer's establishes itself independently at various points in the brain from an early stage and it is the rate at which these clusters grow that determines the speed of a patient's deterioration, not the speed at which they spread. Previously, it was was believed that it started at one specific point in the brain and then spread to other parts in a chain reaction.[899]
- The discovery that brain cells in Alzheimer's patients survived when they were able to block the protein MEG3 that was triggering cell suicide and necroptosis, the removal by the body of dead cells. Alzheimer's patients build-up two toxic proteins, tau and amyloid beta. Amyloid is believed to accumulate in spaces between neurons

---

[892] https://www.labmedica.com/molecular-diagnostics/articles/294806085/index.php
[893] Protein-slaying drugs could be the next blockbuster therapies, *Nature Feature*, 20 March 2019.
[894] Carla Heyworth (2020) Targeting mitochondria to fight aging, *Longevity Technology*, 22 January; https://www.longevity.technology/targeting-mitochondria-to-fight-aging/
[895] https://www.dailymail.co.uk/health/article-15448591/Alzheimers-linked-variants-single-gene.html, https://www.dailymail.co.uk/health/article-15620379/Single-gene-dementia-earlier-cognitive-decline-interventions-midlife.html; https://jamanetwork.com/journals/jamanetworkopen/fullarticle/2845995
[896] A peptide is a 'short chain of amino acids. The amino acids in a peptide are connected to one another in a sequence by bonds called peptide bonds. Typically, peptides are distinguished from proteins by their shorter length, although the cut-off number of amino acids for defining a peptide and protein can be arbitrary'; https://www.nature.com/scitable/definition/peptide-317/
[897] Protein in mitochondria appears to regulate health and longevity, *Science Daily*, 24 June 2020; https://www.sciencedaily.com/releases/2020/06/200624151613.htm
[898] Stimulating immune cells to protect against Alzheimer's, *Neuroscience News*, 10 March 2020.
[899] https://www.telegraph.co.uk/news/2021/10/29/scientists-pinpoint-exactly-alzheimers-grows-brain-breakthrough

in brain cells, leading to brain inflammation. Tau tangles then begin to appear and the brain cells gradually start to die. Scientists believe that drugs that mimicked the blockage of MEG3 could prevent necroptosis.[900]

- The invention of a blood test for identifying Parkinson's disease ten years before symptoms emerge, allowing the early application of precision therapies. It is the second most prevalent neurodegenerative disorder globally and is caused by the brain cells' inability to process a protein called alpha-synuclein. As a result, abnormal clusters of the protein form and damage nerve cells, resulting in movement disorder.[901]
- The Institute of Ageing at Newcastle University and the Mayo Clinic in the US have demonstrated that senescent cells can be selectively killed (using a process known as senolytics) and this helps to postpone multiple age-related disabilities and disease.[902]
- The introduction of rejuvenation medicine that turns back biological age,[903] rather than just slowing it down, by the restoration of the molecular and cellular structure and composition of tissues and organs. One example is the removal of 'zombie' cells, senescent cells that no longer divide, but remain alive, creating difficulties for their environment.[904] Another example is organ regeneration using lymph nodes to regrow functioning organs within a patient's own body, eradicating the problem of organ rejection in transplant patients and solving the problem of organ supply scarcity.[905, 906]
- The use of hyperbaric oxygen therapy to reverse two key indicators of biological aging: telomere length and senescent cells accumulation. In a clinical study, 35 adults over 64 years were placed in a pressurized chamber and given pure oxygen for 90 minutes a day, five days a week for three months. At the end of the trial, the participants' telomeres had increased in length by an average of 20%, while their senescent cells had been reduced by up to 37%.[907]

---

[900] Sarah Knapton (2023) Alzheimer's could cause brain cells to kill themselves, *Daily Telegraph*, 15 September; https://www.telegraph.co.uk/news/2023/09/15/dementia-researchers-uncover-why-brain-cells-die/.

[901] https://www.labmedica.com/molecular-diagnostics/articles/294799502/index.php

[902] Danny Buckland (2019) We're living much longer, but are we healthier?, Raconteur.net, 23 May. Ellie Dolgin (2020) Send in the senolytics, *Nature Biotechnology*, 12 November,

[903] Some scientists argue that biological age is a more useful indicator than chronological age. For example, Prof Jamie Timmons of King's College London argues that 'There's a healthy ageing signature [in your body's cells], and it appears to be prognostic for a number of things including longevity and cognitive decline. It looks like from the age of 40 onwards you can use this to give guidance on how well an individual is ageing'; https://www.bbc.co.uk/news/health-34153135

[904] Aubrey de Grey, co-founder and chief scientific officer, SENS Research Foundation, interviewed in *Longevity Trends 2020*, published by Longevity Leaders, January 2020.

[905] *Longevity Trends 2020*, published by Longevity Leaders, January 2020.

[906] Some scientists question whether it is currently possible to measure biological age accurately. One example is Jay Olshansky, chief scientific officer, Lapetus Solutions. Nevertheless, he has developed a metric based on face age 'which illustrates the documented relationship between how young or old you look relative to your chronological age. It's not a statement that you're this many years younger or older, but it seems to be a reasonable biomarker giving you a clue that you might be aging more slowly or more rapidly'. Interviewed in *Longevity Trends 2020*, published by Longevity Leaders, January 2020.

[907] Anthony Cuthbertson (2020) Human aging reversed in 'Holy Grail' study, *Independent*, 30 November;

- The development of EpiAgePublic, a low-cost method to estimate biological age by analyzing just three key DNA sites in the ELOVL2 gene, a well-known aging marker. The method uses only saliva samples, and contrasts with traditional methods that require the analysis of thousands of DNA regions. The new approach streamlines the process without sacrificing accuracy.[908]
- The development of the Systems Age test by researchers at Yale University, whereby a single blood test can reveal the biological ages of different organs and bodily systems. Traditional biological age tests, such as epigenetic clocks, provide only a single number and fail to show which body systems are most at risk. The new test is capable of assessing aging in 11 systems, including the heart, lungs, brain, metabolism, and immune system. This will help doctors identify which systems are most vulnerable and deliver more personalized strategies for prevention and treatment, ranging from lifestyle changes to targeted therapies.[909]
- Demonstration in an animal model that age-related frailty and immune decline can be halted and even partially reversed using a novel cell-based therapeutic approach. It is known that visceral adipose tissue or belly fat contributes to the development of chronic low-grade inflammation. Researchers at the University of Bern report that certain immune cells in the belly fat play an essential role in regulating chronic low-grade inflammation and downstream aging processes. They show that these immune cells may be used to reverse such processes.[910]
- The identification of 10 genomic loci which influence three key phenotypes[911] (years lived in good health (healthspan), total years lived (lifespan), and survival until an exceptional old age (longevity)). Of these five (FOXO3, SLC4A7, LINC02513, ZW10, and FGD6) have not been reported previously as of genome-wide significance. The majority of these 10 loci are associated with cardiovascular disease and some affect the expression of genes known to change their activity with age. The study also showed the importance of gene sets linked to how the body metabolizes iron, with too much iron in the blood appearing to increase risk of dying earlier. Professor Paul Timmers, one of the authors of the study, said: 'We speculate that our findings on iron metabolism might also start to explain why very

---

https://www.independent.co.uk/life-style/gadgets-and-tech/anti-ageing-reverse-treatment-telomeres-b1748067.html

[908] https://www.labmedica.com/molecular-diagnostics/articles/294804161/index.php

[909] https://www.labmedica.com/molecular-diagnostics/articles/294806711/single-blood-test-reveals-biological-ages-of-different-organs-and-bodily-systems.html

[910] Daniel Brigger, Carsten Riether, Robin van Brummelen, Kira I. Mosher, Alicia Shiu, Zhaoqing Ding, Noemi Zbären, Pascal Gasser, Pascal Guntern, Hanadie Yousef, Joseph M. Castellano, Federico Storni, Neill Graff-Radford, Markus Britschgi, Denis Grandgirard, Magdalena Hinterbrandner, Mark Siegrist, Norman Moullan, Willy Hofstetter, Stephen L. Leib, Peter M. Villiger, Johan Auwerx, Saul A. Villeda, Tony Wyss-Coray, Mario Noti, Alexander Eggel (2020) Eosinophils regulate adipose tissue inflammation and sustain physical and immunological fitness in old age, *Nature Metabolism*; DOI: 10.1038/s42255-020-0228-3

[911] Phenotypes are the observable characteristics of an organism that result from the interaction of its genotype (total genetic inheritance) with the environment. For individuals, this includes characteristics such as height, eye colour and blood type (https://www.britannica.com/science/phenotype; https://www.genome.gov/genetics-glossary/Phenotype).

high levels of iron-rich red meat in the diet has been linked to age-related conditions such as heart disease'.[912]

- The identification of proteins associated with aging and increased frailty.913 A study of 4265 proteins measured in plasma found that 55 were positively associated with frailty, in particular, fatty acid-binding protein FABP and ANTR2.914
- The development by biotech company Elevian of drugs based on GDF11 (growth differentiation factor 11), a Harvard University-discovered protein linked to age-related diseases. The work on GDF11 – which involved a technique called parabiosis in which the circulatory systems of young and old mice were combined to allow blood to flow between the animals – suggested that injecting the protein into old mice regenerated cardiac, brain and muscle tissue.[915]
- By increasing the amount of the protein sestrin in fruit flies, researchers have been able to extend their lifespan and at the same time these flies were protected against the lifespan-shortening effects of a protein-rich diet. The researchers could further show that sestrin plays a key role in stem cells in the fly gut thereby improving the health of the fly.[916]
- The detection of cell senescence using fluorescence imaging and flow cytometry analysis.[917]
- The discovery that pro-inflammatory cytokines[918] induce cellular senescence and hence aging by activating EGFR (Epidermal Growth Factor Receptor) signaling. The activity of five senescence-inducing cytokines (IL-1β, IL-13, MCP-2, MIP-3α, and SDF-1α) could be significantly inhibited by treatment with cetuximab (an antibody targeting EGFR), gefitinib (a small molecule inhibitor of EGFR), and EGFR knockdown (the targeted reduction rather than inhibition of the EGFR peptide).[919]

---

[912] Paul R. H. J. Timmers, James F. Wilson, Peter K. Joshi, and Joris Deelen (2020) Multivariate genomic scan implicates novel loci and haem metabolism in human aging, *Nature Communications* volume 11, Article number: 3570 (2020); https://doi.org/10.1038/s41467-020-17312-3. David Nield (2020) Study of Over 1 Million People Finds Intriguing Link Between Iron Levels And Lifespan, *Science Alert*, 17 July; https://www.sciencealert.com/a-study-of-1m-people-finds-a-strange-link-between-iron-levels-and-long-life

[913] Frailty is a state of decreased physiological reserve and increased vulnerability to adverse outcomes in aging, and is characterized by dysregulation across various biological pathways.

[914] Sanish Sathyan, Tina Gao, Sofiya Milman, Nir Barzilai, Joe Verghese, Sanish Sathyan and Emmeline Ayers (2020) Plasma proteomic profile of frailty, *Aging Cell,* https://doi.org/10.1111/acel.13193

[915] Ben Adams (2020) Anti-aging biotech Elevian raises $15M as it looks to the clinic,*Fierce biotech,* 24 November; https://www.fiercebiotech.com/biotech/anti-ageing-biotech-elevian-raises-15m-as-it-looks-to-clinic

[916] Jiongming Lu, Ulrike Temp, Andrea Müller-Hartmann, Jacqueline Esser, Sebastian Grönke, Linda Partridge. Sestrin is a key regulator of stem cell function and lifespan in response to dietary amino acids, *Nature Aging*, 2020; doi: 10.1038/s43587-020-00001-7

[917] For example, by using Cell Meter™ Cellular Senescence Activity Assay Kits.

[918] Cytokines are a broad category of small proteins or peptides – such as chemokines, interferons, interleukins, lymphokines, and growth factors – which are secreted by certain cells of the immune system and have an effect on – by sending signals to – other cells; https://en.wikipedia.org/wiki/Cytokine

[919] Dongsheng Shang, Danlin Sun, Chunyan Shi, Jun Xu, Mingxiang Shen, Xing Hu and Hanqing Liu (2020) Activation of epidermal growth factor receptor signaling mediates cellular senescence induced by certain pro-inflammatory cytokines, *Aging Cell*, 22 April; https://doi.org/10.1111/acel.13145

- The discovery that lysine glycation in collagen appears to contribute to tendon stiffening with age and in diabetes.[920]
- A study led by University College London suggests that weight management could play a significant role in reducing the risk of developing dementia, after finding that obesity increases the risk of dementia up to 15 years later. The study showed that people who are obese in late adulthood face a 31% increased risk of dementia compared with those whose body mass index is normal. The risk is particularly high for women.[921]
- Researchers at the University of Bonn have discovered a receptor in mice that regulates both increasing abdominal girth and shrinking muscles, two common side effects of aging. Experiments with human cell cultures suggest that the corresponding signaling pathways might also exist in humans.[922]
- Adoptive cell therapies (ACTs) which involve the use of immune cells as anti-cancer agents and hold promise for the treatment of adult and paediatric cancer, ranging from liquid to solid tumors. One type of ACT involves chimeric antigen receptor (CAR)-engineered immune cells, with two CAR T-cell-based therapies recently approved by the US Food and Drug Administration, paving the way for the development of additional ACT therapies.[923]
- The discovery that CAR-T (chimeric antigen receptor cell therapy) can also be used in the treatment of autoimmune diseases, such as lupus, which results from the immune system attacking healthy cells, leading to fatigue and joint pain.[924]
- Identification of a biomarker for tumour initiating (or cancer stem) cells.[925]
- Early diagnosis of certain cancers (e.g., ovarian and brain) by identifying genetic errors in DNA.[926]
- A new DNA test evaluates biomarkers in 517 cancer-relevant genes across 30 types of solid tumours.[927]
- Cardiac blood markers – typically used to assess heart health – have been found to strongly predict future cancer risk, even in individuals with no symptoms or history of cardiovascular disease.[928]

---

[920] Melanie Stammers, Irina M. Ivanova , Izabella S. Niewczas, Anne Segonds-Pichon , Matthew Streeter , David A. Spiegel , and Jonathan Clark (2020) Age-related changes in the physical properties, cross-linking, and glycation of collagen from mouse tail tendon, *J Biol Chem*; doi: 10.1074/jbc.RA119.011031

[921] Obesity linked to higher risk of dementia, *Pharma Times*, 29 June 2020; http://www.pharmatimes.com/news/obesity_linked_to_higher_risk_of_dementia_1343249

[922] University of Bonn. Receptor makes mice strong and slim: Molecule that regulates two side effects of aging identified, ScienceDaily, 25 June 2020; www.sciencedaily.com/releases/2020/06/200625115916.htm

[923] Katy Rezvani, Marco Ruella, and Robbie Majzner (2020) Advances in Adoptive Cell Therapies, Cell Press webinar, 16 July.

[924] https://www.ft.com/content/a974f4c1-bb8a-4a1b-9d88-a2cf14be5c6e

[925] Labmedica.com, 28 November 2019.

[926] Rhys Blakely (2020) Cancer code offers hope of treatment decades early, *The Times*, 6 February.

[927] https://www.labmedica.com/molecular-diagnostics/articles/294792025/groundbreaking-dna-test-evaluates-biomarkers-in-517-cancer-relevant-genes-across-30-types-of-solid-tumors.html

[928] https://www.labmedica.com/molecular-diagnostics/articles/294805451/cardiac-blood-markers-can-strongly-predict-future-cancer-risk.html

- The development of a DNA biosensor to enable early diagnosis of cervical cancer.[929]
- A new metabolism-based blood test detects multiple cancer types prior to symptoms.[930]
- The development of a sterilizable nanowire-based device that can extract urinary microRNAs and use it as a liquid biopsy to detect cancers of the central nervous system.[931]
- Researchers at the Georgia Institute of Technology in the US have invented a microfluidic chip called the Cluster-Well which can precisely locate each cell in a blood sample and determine if it is cancerous. This could lead to earlier and more targeted treatment.[932]
- A new liquid biopsy blood test that can detect cancer tumour DNA in the blood, allowing for 'live monitoring' of both disease and treatment. It was first used to detect brain tumours where a conventional biopsy is not possible.[933] It has subsequently become a standard test for lung cancer and could expand to cover six types of cancer, including breast cancer. It has been described it as a 'golden key' to unlock personalised cancer treatment.[934]
- A treatment that reverses aggressive and incurable blood cancer by editing the DNA in white blood cells to transform them into a cancer-fighting 'living drug'. T-cells seek out and destroying threats, but in T-cell acute lymphoblastic leukaemia they grow out of control.[935]
- Immunotherapy – the re-education of an individual's own immune cells to fight diseases such as cancer.[936] An immunotherapy drug, AFM24, has been shown to work in patients with advanced cancers that had stopped responding to treatment, including bowel, lung and pancreatic cancers.[937]

---

[929] https://www.labmedica.com/technology/articles/294799669/dna-biosensor-enables-early-diagnosis-of-cervical-cancer.html

[930] https://www.labmedica.com/molecular-diagnostics/articles/294793553/index.php; https://www.labmedica.com/molecular-diagnostics/articles/294788864/blood-based-liquid-biopsy-test-accurately-detects-more-than-fifty-types-of-cancer.html;

[931] https://www.labmedica.com/molecular-diagnostics/articles/294788818/a-nanowire-based-liquid-biopsy-method-for-detection-of-tumors-of-the-central-nervous-system.html

[932] https://www.labmedica.com/molecular-diagnostics/articles/294794252/index.php: 'Cancer spreads via circulating tumor cells (CTCs) that travel through the blood to other organs, and they are nearly impossible to track. When a tumor starts metastasizing, it sheds its cell into the blood. An individual cell often doesn't survive the bloodstream on its own, but clusters of cells are much more robust and can travel to other organs, effectively pushing the cancer to a metastatic state [i.e., stage 4]. CTCs have proven difficult to study, let alone treat. Blood contains billions of cells per milliliter, and only a handful of those cells would be CTCs in a patient with metastatic cancer'.

[933] https://www.labmedica.com/molecular-diagnostics/articles/294795854/blood-test-helps-diagnose-inaccessible-brain-tumors.html

[934] https://www.telegraph.co.uk/news/2025/05/29/nhs-blood-test-lung-cancer-peter-johnson-liquid-biopsy/

[935] https://www.bbc.co.uk/news/articles/cj38ymeyg4mo

[936] Siddhartha Mukherjee (2022) *The Song of the Cell: An Exploration of Medicine and the New Human*, Simon & Schuster; https://www.simonandschuster.com/books/The-Song-of-the-Cell/Siddhartha-Mukherjee/9781982117351

[937] https://www.telegraph.co.uk/news/2022/04/08/new-killer-cancer-treatment-stops-one-three-tumours-growing

- The development of tests that can transform cancer treatments. For example, a blood test developed by the Vancouver Prostate Centre and BC Cancer (British Columbia, Canada) analyzes the DNA that metastatic cancers shed into the bloodstream, known as circulating tumor DNA. By sequencing the entire genome of this ctDNA, the test reveals characteristics that are unique to each patient's cancer, giving doctors new tools to develop more personalized treatment plans.[938]
- The development by Moderna and Merck of a personalized cancer vaccine, based on immunotherapy and designed to prime the immune system so the body can generate a response based on a person's specific type of cancer tumour, using the same mRNA technology as in Covid-19 vaccines.[939] When used in combination with Keytruda, it has reduced the risk of death or relapse in patients with the most deadly form of skin cancer by half after three years.[940] In May 2024, the UK started the world's first bowel cancer trial designed in partnership with BioNTech (which had co-developed the first-ever mRNA Covid-19 vaccine).[941]
- Scientists at the US cancer research hospital City of Hope[942] have made a breakthrough against the proliferating cell nuclear antigen (PCNA) protein which in a mutated form helps to replicate expanding cancer tumours. They have developed a molecule, named AOH1996, which targets and kills the mutated PCNA. If clinical trials are successful, AOH1996 could be incorporated in a cancer-stopping pill which would provide protection against breast, prostate, brain, ovarian, cervical, skin and lung cancers.[943]
- The development of an in vitro diagnostic test to detect hundreds of genetic variants that could indicate a higher likelihood of developing specific kinds of cancer.[944]
- The development of an implantable ultrasound device that can open the blood-brain barrier and hence offers the possibility of more effective treatment for the range of neurocognitive diseases (including brain cancer) that previously had limited treatment options due to the blood brain barrier.[945]
- The development of an mRNA cancer vaccine to target glioblastoma, the most aggressive form of brain tumor.[946]

---

[938] https://www.labmedica.com/molecular-diagnostics/articles/294793945/first-of-its-kind-blood-test-could-transform-cancer-treatment.html

[939] https://www.telegraph.co.uk/news/2022/12/13/skin-cancer-vaccine-based-covid-jab-technology-hailed-game-changer; https://www.cancerresearch.org/treatment-types/cancer-vaccines;, https://www.cancer.net/navigating-cancer-care/how-cancer-treated/immunotherapy-and-vaccines/what-are-cancer-vaccines

[940] https://www.cnbc.com/2023/12/14/moderna-merck-cancer-vaccine-reduces-risk-of-skin-cancer-return.html

[941] https://www.telegraph.co.uk/news/2024/05/31/nhs-patients-personalised-cancer-vaccines-world-first-trial

[942] https://www.cityofhope.org/

[943] The molecule is named after Anna Olivia Healey who was born in 1996 but who sadly did not survive cancer; https://metro.co.uk/2023/08/01/cancer-cure-pill-treatment-scientists-19228101/

[944] https://www.labmedica.com/molecular-diagnostics/articles/294798809/first-of-its-kind-dna-test-can-assess-predisposition-for-dozens-of-cancer-types.html

[945] Dr Adam Worthalter, neurosurgeon at Northwestern Memorial Hospital, speaking at the Fasano Longevity Conference, Washington DC, 6 November 2023.

[946] https://medicalxpress.com/news/2024-05-mrna-cancer-vaccine-triggers-fierce.html

- The introduction of a new assay to detect and treat acute myeloid leukemia.[947]
- Anastrozole, taken daily, halves the risk of breast cancer (at a cost of £0.04 per day).[948]
- The introduction of relugolix, an androgen deprivation therapy (ADT) for treating prostate cancer in the form of a pill, saving on hospital injections.[949]
- A new targeted form of radiotherapy, radioligand therapy, developed by Novartis, which completely cleared cancer that had spread around patients' bodies in just six months.[950]
- The development of nanomedicine, the application of nanomaterials in targeted drug delivery for tumors, is helping to improve chemotherapy outcomes. Nanoparticle drug delivery systems can enhance drug solubility, alter drug distribution in the body, improve drug targeting, thereby enhancing therapeutic effects, and reducing adverse reactions. A number of nanocarriers have been developed for drug delivery, such as lipid-based nanocarriers, inorganic nanocarriers, and polymer nanoparticles. These have good biocompatibility and biodegradability and can stably transport drugs, improve drug solubility, and stability.[951]
- The levels of antibodies against ALDOA and FH provide novel predictors of ischemic stroke, including transient ischemic attack (TIA) and cerebral infarction (CI), which are induced by atherosclerosis.[952]
- A new blood-based cardiovascular risk test for more accurate risk prediction (of heart disease and sudden cardiac arrest) and patient management.[953]
- The importance of selenium in antioxidant mixtures designed to reduce all-cause mortality, in particular, from cardiovascular disease and cancer.[954]
- A genetic testing procedure combined with ultrasound to detect high cardiovascular risks.[955]

---

[947] https://www.labmedica.com/molecular-diagnostics/articles/294799362/new-assay-to-revolutionize-detection-and-treatment-of-acute-myeloid-leukemia.html
[948] https://www.telegraph.co.uk/news/2023/11/07/breast-cancer-risk-halved-daily-pill-anastrozole-nhs
[949] https://www.telegraph.co.uk/news/2024/07/19/home-pill-for-advanced-prostate-cancer-on-nhs/
[950] https://www.ft.com/content/a955b66c-89ac-4d2f-83dc-2b93baa4d56a
[951] Nanotechnology revolution: Exploring various pathways for drug delivery, *Medchemexpress*, 23 July 2024.
[952] Hardening of the arteries caused by a buildup of plaque in the inner lining of an artery; https://www.labmedica.com/clinical-chem./articles/294789093/aldoa-and-fh4-antibodies-associated-with-cerebrovascular-disease.html
[953] https://www.labmedica.com/hematology/articles/294792002/elisa-blood-test-uses-innovative-biomarker-to-detect-heart-disease-and-sudden-cardiac-arrest.html; https://www.labmedica.com/hematology/articles/294789202/novel-ai-driven-cardiac-blood-test-provides-highly-accurate-prediction-of-one-year-risk-for-heart-attack-stroke-or-cardiac-death.html
[954] David J A Jenkins, David Kitts, Edward L Giovannucci, Sandhya Sahye-Pudaruth, Melanie Paquette, Sonia Blanco Mejia, Darshna Patel, Meaghan Kavanagh, Tom Tsirakis, Cyril W C Kendall, Sathish C Pichika, John L Sievenpiper, Selenium, antioxidants, cardiovascular disease, and all-cause mortality: a systematic review and meta-analysis of randomized controlled trials, *The American Journal of Clinical Nutrition*, nqaa245, https://doi.org/10.1093/ajcn/nqaa245
[955] https://www.labmedica.com/molecular-diagnostics/articles/294801033/new-genetic-testing-procedure-combined-with-ultrasound-detects-high-cardiovascular-risk.html

- A genetic type 1 diabetes risk test identifies individuals at high risk of developing T1D.[956]
- The development of technology by Bit.Bio to reprogram stem cells to make any human cell desired.[957] In June 2023, scientists at the University of Cambridge and the California Institute of Technology revealed that they have used stem cells to create synthetic human embryos, avoiding the need for eggs or sperm. The embryos resemble those in the earliest stages of human development and could be used to gain a better understanding of genetic disorders.[958]
- The start of a research program on reproductive longevity and equality as it relates to aging and ending the threat of age-related disease at a new Center for Reproductive Longevity and Equality (CRLE) at the Buck Institute. The center's goal is 'is to conduct basic research to understand the mechanisms of female reproductive aging and develop strategies to prevent or delay ovarian aging. The end of fertility sets off a cascade of negative health effects in women's bodies that impact bone, cognitive, cardiovascular and immune function. We want to understand why human women undergo a decline in fertility (menopause), why it varies between individuals, and why it correlates with life span. We think that understanding the limits on mammalian female reproductive capacity may provide important clues about aging in other tissues'.[959]
- A breakthrough in biosensing technology enables new methods of early disease detection. Nanopores are tiny openings that can detect individual molecules as they pass through, enabling the analysis of biomolecules like DNA and proteins found in the early stages of diseases. In the past, detection at extremely low concentrations has been challenging, but there have been new developments in nanotechnology for biomolecule detection and analysis. Researchers at SMU Lyle (Dallas, TX, USA) have combined DNA structures with solid-state nanopores (creating a 'hybrid nanopore' system) to enhance the detection of low-concentration proteins. Many diseases, such as cancer and neurodegenerative disorders, are marked by proteins present in very small quantities. The hybrid nanopore's ability to detect these low-concentration proteins could lead to earlier diagnoses and more effective treatment outcomes.[960]

Huge advances are expected to follow the final decoding of the entire human genome[961] in March 2022.[962] Cost and speed have fallen dramatically. A whole genome cost $100m in

[956] https://www.labmedica.com/molecular-diagnostics/articles/294807475/worlds-first-genetic-type-1-diabetes-risk-test-enables-early-detection.html
[957] Tom Whipple (2020) Bit.Bio: British firm cracks code for stem cells, *The Times*, 27 October.
[958] https://www.theguardian.com/science/2023/jun/14/synthetic-human-embryos-created-in-groundbreaking-advance
[959] https://www.buckinstitute.org/lab/center-for-reproductive-longevity-and-equality/. See also: Hannah Kuchler (2024) Ovaries are an enigma that could unlock human lifespan, *Financial Times*, 1 February; https://www.ft.com/content/9599c28e-aa49-46fe-ace9-266bd4fe1023
[960] https://www.labmedica.com/clinical-chem./articles/294803382/biosensing-technology-breakthrough-paves-way-for-new-methods-of-early-disease-detection.html
[961] A human's complete set of DNA.
[962] Timeline - Genetic breakthroughs:
- December 1999 - First human chromosome is sequenced

2001, but in 2022 it was $400 and is anticipated to be just $100 by 2024. The development of CRISPR technology for editing genomes allows scientists to change DNA sequences and modify gene function, so that, for example, genetic defects can be corrected and the spread of diseases can be prevented. Dr Kevin Esvelt, a biologist at the MIT Media Lab, devised the CRISPR-based gene drive in 2013. This uses CRISPR 'to hack the laws of inheritance' by allowing scientists 'to genetically modify a few individuals that then spread a modified gene throughout an entire population, and eventually, every population around the world'.[963] Scientists claim that this will open the way to precision medicine for everybody. Professor Sir Mark Caulfield, former chief scientist at Genomics England, said: 'We have got a fabulous future. We have only scratched the surface of what the whole genome can offer'. The first benefit will be the early diagnosis of illness and personalized medicine. This will be followed by the correction of faulty genes via gene therapy. As an early example of gene therapy, scientists, using a technique called optogenetics, have added light-sensitive proteins to a man's retina, partially restoring his sight.[964] All this will help to reduce working age sickness and extend the working life, with knock-on benefits for the sustainability of the pension system.[965] Another example is the use of gene therapy to repair hearing loss caused by auditory neuropathy disrupting nerve impulses travelling from the inner ear to the brain as a result of a faulty gene.[966]

The success in the decoding of the human genome has led to the introduction of gnomic medicine which uses genomic information about an individual as part of their clinical care (e.g., for diagnostic or therapeutic decision-making).[967] Further, according to Yurkovich et al. (2023), 'By assessing and optimizing the health trajectory of each individual using a data-driven personalized approach that reflects their genetics, behaviour and environment, we can start to address [the challenges of an ageing population and its inherent burden of chronic diseases and rising costs]. This assessment includes longitudinal phenome

- April 2003 - Heads of government of Britain, the US, Japan, France, Germany, and China announce the successful sequencing of the entire human genome
- September 2005 - The chimpanzee genome is sequenced
- December 2009 - The first comprehensive analysis of cancer genomes is published, including lung cancer and malignant melanoma
- May 2010 - The Neanderthal genome is sequenced
- December 2018 - The 100,000 genomes project is completed, sequencing 100,000 genomes from patients affected by a rare disease or cancer
- March 2022 - Scientists finally decode the entire human genome

Source: https://www.telegraph.co.uk/business/2022/08/19/britains-path-economic-national-renewal-genome-revolution

[963] Su Bin Moon, Do Yon Kim, Jeong-Heon Ko and Yong-Sam Kim (2019) Recent Advances in the CRISPR Genome Editing Tool Set, *Experimental & Molecular Medicine*, 51: 1–11 ; https://www.media.mit.edu/articles/gene-drives-could-stop-the-world-s-oldest-problems-kevin-esvelt-wants-to-make-sure-they-don-t-start-any/

[964] https://www.nytimes.com/2021/05/24/science/blindness-therapy-optogenetics.html

[965] https://www.telegraph.co.uk/business/2022/08/19/britains-path-economic-national-renewal-genome-revolution

[966] https://humanprogress.org/uk-toddler-has-hearing-restored-in-world-first-gene-therapy-trial/

[967] https://www.genome.gov/health/Genomics-and-Medicine; https://www.genomicsengland.co.uk/genomic-medicine

measures, such as the blood proteome and metabolome, gut microbiome[968] composition and function, and lifestyle and behaviour through wearables and questionnaires'.[969] The first Center for Phenomic Health, whose aim is to 'fuel the future of healthy aging', was set up at the Buck Institute.[970]

In December 2025, the Synthetic Human Genome Project, funded by the Wellcome Trust, announced that it had demonstrated that a synthetic human chromosome – the DNA structure carrying genetic information – can be assembled inside a mouse cell. The synthetic chromosome could then be transferred to a human cell to replace one of the two natural chromosomes without causing damage. The whole process can be repeated and the second natural chromosome expelled to produce a human cell with two synthetic chromosomes. In this way it is possible to synthesize a human genome. The achievement has been described as a 'landmark step for synthetic biology [which] lays essential groundwork for the engineering of synthetic human genomes'. One possible application is to make human cells resistant to viruses, such as by repopulating the liver of immunocompromised patients to prevent them picking up infections. Another is to make cells with synthetic genomes tailored precisely for a particular type of cellular therapy.[971]

Dr Verdin expects the first anti-aging drugs to become available on the market in the next 5-10 years, following the completion of successful clinical trials. He also believes the new drugs will revolutionize the whole process of medical intervention which have traditionally focused on treating a specific disease, like heart or lung disease: 'Aging biology presents a different way of organizing medicine and of treating disease. Aging affects every single organ, so if your intervention targets an aging pathway, you will affect the development of diseases in different organs. That doesn't fit in the traditional field of medicine. So, one of the biggest challenges we face… is convincing people that we should be studying disease in the context of pathways that are universal across different organs. We need to change the way that we practice medicine to aim for a preventative approach'.[972] This point is reinforced by Steven Braithwaite, chief scientific officer of Alkahest: 'Our long-term goal is that we will develop therapeutics that modulate the biology of aging and will have impact across multiple disorders'.[973] Joan Mannick, chief medical officer of resTORbio, goes further: 'In the future we may be able to personalize aging-related therapeutics. For

[968] The collection of all microbes, such as bacteria, fungi, viruses, and their genes, that naturally live [in the gut]; https://www.niehs.nih.gov/health/topics/science/microbiome#.
[969] Yurkovich, J.T., Evans, S.J., Rappaport, N., Boore, J. L., Lovejoy, J. C., Price, N. D., and Hood, L. E. (2023) 'The Transition from Genomics to Phenomics in Personalized Population Health', *Nature Reviews Genetics*, https://doi.org/10.1038/s41576-023-00674-x. Phenomics is the systematic measurement and analysis of qualitative and quantitative traits, including clinical, biochemical, and imaging methodologies, for the refinement and characterization of a phenotype (https://www.sciencedirect.com/topics/medicine-and-dentistry/phenomics).
[970] https://www.buckinstitute.org/lab/center-for-phenomic-health/
[971] https://www.ft.com/content/8b06f15b-3a4e-49e7-8993-e6d6d5fc2309
[972] Interviewed in *Longevity Trends 2020*, published by Longevity Leaders, January 2020.
[973] Steven Braithwaite, chief scientific officer, Alkahest, interviewed in *Longevity Trends 2020*, published by Longevity Leaders, January 2020.

instance, it would be useful to develop biomarkers of aging-related biochemical pathways and then use therapeutics targeting specific biochemical pathways in …specific patients', similar to how cholesterol became a biomarker for the use of statins.[974] A huge investment is being made in healthcare innovation to slow the aging process by organizations like the Deep Knowledge Group.[975]

Governments are also setting up life science strategies. For example, the UK government introduced one in 2017 and updated it in 2021, building on the knowledge gained from the Covid-19 pandemic to tackle future disease missions, such as dementia research, the early-stage diagnosis and treatment of diseases such as cancer, and prevention of cardiovascular diseases. There will be greater use of genomics and health data to provide much deeper, real world evidence about the safety of new medicines and health technologies.[976] There will also be greater use of oncology medicines, such as AstraZenica's Enhurtu (for treating breast cancer), Tagrisso (lung cancer), Imfinzi (limited-stage small cell lung cancer) and Lynparza (ovarian cancer). Dave Frederickson, head of oncology at AZ, believes it will soon be possible 'to eliminate cancer as a cause of death'.[977]

In April 2022, leading life sciences companies and Innovate UK called for the development of a national vision on cell and gene therapies (CGTs) in the UK.[978] CGTs are treatments based on human cells or genes and a form of advanced therapy medicinal product (ATMPs). Compared to small molecules and protein-based treatments, such as monoclonal antibodies, which require repeated administration to treat the underlying conditions, CGT treatments offer a solution in which a single dose can provide a durable therapeutic effect. Nearly 300 new CGTs were currently in development, but the UK needs to scale-up its manufacturing capacity to meet demand for CGTs in future. There was also a compliance challenge, since CGTs often have a very short shelf life.

Genetic modifications in animals are helping to extend human life expectancy. An example is the first transplant of a genetically modified pig kidney into a living human at Massachusetts General Hospital in Boston in March 2024. Genetically modified pigs can provide kidneys, livers, and hearts to help overcome the shortage of these organs for people who need transplants. The pigs' DNA is genetically modified so the organs will not be rejected by the human body. Other gene-editing and cloning technologies are also being used to solve the shortage of organs for human transplantation.[979]

---

[974] Joan Mannick, chief medical officer, resTORbio, interviewed in *Longevity Trends 2020*, published by Longevity Leaders, January 2020.

[975][975] https://www.dkv.global/

[976] https://www.pinsentmasons.com/out-law/news/genomics-and-health-data-central-to-uk-life-sciences-vision

[977] https://www.telegraph.co.uk/business/2023/01/27/meet-scientist-working-eliminate-terminal-cancer/; https://www.telegraph.co.uk/business/2024/04/05/pioneering-lung-cancer-drug-offers-hope-for-patients/

[978] https://ct.catapult.org.uk/sites/default/files/publication/National%20Cell%20and%20Gene%20Therapy%20Vision%20for%20the%20UK.pdf

[979] https://www.npr.org/sections/health-shots/2024/03/21/1239790816/first-pig-kidney-human-transplant

Neuroscientist Ariel Zeleznikow-Johnston predicts that one day it will be possible to 'abolish death' by recording an individual's 'connectome' (a map of brain connections) before they died and then using low-temperature 'vitrification' to preserve the brain in such a state that future technology would be able to read its connectome and recreate it.[980]

Amongst these positive developments, there have been some negative ones. A key example in 2022 was the exposure by the journal *Science* in July that the study by Lesné et al (2006) published in the journal *Nature* on the causes of Alzheimer's disease may have been based on evidence tampering using 'manipulated' data.[981] The 2006 study concluded that Alzheimer's is triggered by a build-up of amyloid beta plaques in the brain following experiments in which amyloid beta injected into young mice brought on dementia. However, the *Science* investigation claims to have found evidence that the images of amyloid beta in mice had been doctored by combining photos from different experiments. German psychiatrist Alois Alzheimer first identified plaques in the brains of dementia patients in 1906 and in 1984 amyloid beta was found to be their main component. Hundreds of different therapies targeting amyloid in the brain were trialled, but since they all failed, futher experimentation was abandoned until the 2006 paper. Since then billions of dollars have been spent trialling new therapies to remove amyloid from the brain – again without success. Yet in June 2022, the US Food and Drug Administration approved the drug aducanumab (marketed as Aduhelm) to slow cognitive decline in people with mild memory and thinking problems. It was the first approved treatment to attack the disease process of Alzheimer's instead of just addressing dementia symptoms. This was despite the fact that the FDA's own independent advisory committee argued that there was insufficient evidence that the drug – which costs $56,000 a year – can help patients.[982] The authors of the 2006 paper responded by saying they 'still have faith' that amyloid is a cause of Alzheimer's. Alzheimer's Research UK said: 'the research that has been called into question is focused on a very specific type of amyloid, and these allegations do not compromise the vast majority of knowledge built up during decades of research into the role of this protein in the disease'.[983]

Also related to Alzheimer's was the publication in April 2026 of a major review of 20,000 patients by the Cochrane Institute which assessed the clinical benefits and harms of amyloid-beta-targeting monoclonal antibodies aducanumab, bapineuzumab, crenezumab, donanemab, gantenerumab, lecanemab, ponezumab, remternetug, and solanezumab in people with mild cognitive impairment or mild dementia due to Alzheimer's disease. It found they made 'little to no difference' in slowing the disease or improving quality of life and instead could cause brain swelling and bleeding. Dr Francesco Nonino, a neurologist and epidemiologist, a director at the IRCCS Institute of Neurological Sciences of Bologna, and the lead author of the review said: 'Decades of expensive dementia research have

[980] Ariel Zeleznikow-Johnston (2024) *The Future Loves You: How and Why We Should Abolish Death*, Allen Lane, London.
[981] https://www.science.org/content/article/potential-fabrication-research-images-threatens-key-theory-alzheimers-disease
[982] https://www.nytimes.com/2021/06/07/health/aduhelm-fda-alzheimers-drug.html
[983] https://www.telegraph.co.uk/news/2022/07/21/manipulated-alzheimers-data-may-have-misled-research-16-years/

focused on the "amyloid hypothesis", the idea that Alzheimer's disease is primarily driven by plaques that build up in the brain. It was believed that by removing amyloid plaques from the brain, we could have, if not a reversal of the disease, then at least slow the progression. This became the springboard for a whole line of research – and at first it appeared to succeed. A succession of "wonder drugs", most notably lecanemab[984] and donanemab,[985] were shown to clear the plaques. It was hoped they could turn the tide on the disease. However, results were mixed, raising questions about how well the drugs worked and how safe they were. This prompted us to launch the Cochrane review to see how these drugs perform in terms of results'.[986] There is, however, a more recent drug trontinemab which cleared the amyloid plaque in Alzheimer's patients more rapidly than any current licensed drug. Nine in 10 patients prescribed trontinemab experienced amyloid clearance within 28 weeks, eliminating the visible markers of disease. One group of researchers will examine whether the drug could be given to those without any symptoms in order to prevent the disease. Another group will assess the efficacy and safety of trontinemab in participants with early symptomatic Alzheimer's disease (mild cognitive impairment to mild dementia due to AD).[987]

Another negative development is the finding by Binghamton University in the US that early retirement can accelerate cognitive decline at older ages. The finding was based on an examination of China's New Rural Pension Scheme (NRPS) and the Chinese Health and Retirement Longitudinal Survey (CHARLS). The most significant indicator of cognitive decline was delayed recall which is an important predictor of dementia and was associated with increased social isolation. The findings were similar to those in higher income countries, such as the US, UK, and EU.[988]

Yet another negative development is what has been described as a mysterious new 'epidemic' of abdominal cancers in younger people. It could be partly genetic. For example, one in 350 people have Lynch syndrome, a hereditary cause of bowel, womb, ovary and pancreatic cancers. Increasing survival rates will increase the numbers with the syndrome in subsequent generations. It could also be due to changes to the gut microbiome,

[984] Lecanemab contains antibodies which target the protein amyloid it starts to join with other amyloids to form clumps called fibrils which, in turn, join together to form plaques which disrupt neuron function. The drug was authorized for use in the US in January 2023, with an annual cost of $26,500 per patient. However, it was recognised that there are potential side effects, including swelling and potential bleeding in the brain; https://www.telegraph.co.uk/news/2024/08/21/alzheimers-wonder-drug-lecanemab-approved
[985] Initial trials appeared to show that donanemab slowed down the progression of Alzheimer's by more than 20%, with greater impact in people at an earlier stage of the syndrome; https://www.alzheimers.org.uk/news/2023-07-17/new-drug-donanemab-turning-point-alzheimers
[986] https://www.cochranelibrary.com/cdsr/doi/10.1002/14651858.CD016297/full; https://www.telegraph.co.uk/health-fitness/conditions/dementia/neurologist-miracle-dementia-drugs-dont-work
[987] https://www.telegraph.co.uk/news/2025/07/28/new-drug-could-halt-alzheimers-disease/; https://www.cochranelibrary.com/central/doi/10.1002/central/CN-02914525/full
[988] https://www.pensionpolicyinternational.com/early-retirement-can-accelerate-cognitive-decline-among-the-elderly-research-shows/

since the composition of gut bacteria – as a result of dietary or environmental factors – can influence inflammation levels and increase the risk of early-onset cancer.[989]

As a final example, Gilmer et al. (2023) point out that female-specific aging trajectories are understudied. While the use of model organisms, such as worms, fruit flies, and mice, has helped researchers understand many aging processes, most do not match human sex specificity. As a result, there is a lack of data on how pregnancy, breastfeeding, and menopause impact aging-related diseases. Animal research is based on the assumption that the model organisms and humans have similar physiological characteristics, but there are significant differences between the physiology of these organisms and female reproductive biology. One example is bone mass: the bone mass of female rodents does not decline more than that of male rodents, but human females experience osteoporosis four times more often than human males. Similarly, with Alzheimer's disease and other types of dementia: these are more common in human females than age-matched human males, but female rodents have better retained memory-related functions over time than age-matched male rodents. The consequence is worse health outcomes with higher morbidity in the female population than age-matched human males. The authors recommend funding for more research on the impact of menopause, pregnancy, and breastfeeding on aging and disease progression and the use proper animal models and experimental setups, thus improving how their studies handle the particular ways in which females age.[990]

***Preventative health care and later life wellness***

The previous subsection highlights the importance of preventative health care – given how expensive it is to treat noncommunicable diseases, such as heart disease, cancer, diabetes, and dementia, which account for around 70% of deaths globally.

The OECD estimates that around 40% of cancer cases are preventable and mortality can be reduced through earlier diagnosis and the provision of more timely and effective treatments. Confirmation of this comes from the UK. Lung cancer is the most lethal form and in the UK it causes an average of 35,000 deaths per year, where the average stage of diagnosis is Stage 3. There was no nationwide screening program, but in 2019, the NHS introduced a lung cancer screening pilot scheme using low dose CT scanning for current and ex-smokers aged between 55 and 75, with 77% of patients being diagnosed with lung cancer at Stages 1 or 2 (compared with 33% previously). In October 2022, the NHS began to roll out of the program nationally.[991]

A multi-cancer early detection test has been developed by Galleri.[992] It is a simple blood test that screens for many of the deadliest cancers before they become symptomatic.

[989] https://www.telegraph.co.uk/news/2024/03/23/doctors-warn-abdominal-cancer-epidemic-princess-diagnosis/
[990] Gabrielle Gilmer, Zachary R. Hettinger, Yetsa Tuakli-Wosornu, Elizabeth Skidmore, Julie K. Silver, Rebecca C. Thurston, Dawn A. Lowe and Fabrisia Ambrosio (2023) Female aging: when translational models don't translate, Nature Aging, 3: 1500–1508.
[991] Murray et al. (2022).
[992] https://www.galleri.com

Currently, only five cancer types have specific screening tests: colorectal, lung, breast, cervical, and prostate. The Galleri test can detect more than 50 kinds of cancer. According to Professor Eric Klein of the Glickman Urological Kidney Institute: 'Twelve cancers, including anal, bladder, colorectal, esophageal, head and neck, liver/bile-duct, lung, lymphoma, ovary, pancreatic, plasma-cell neoplasm and stomach cancer, account for about two-thirds of all cancer deaths in the US. For these 12, Galleri finds about 40% of stage I cancers, 67% of stage II cancers, 80% of stage III cancers and 95% of stage IV cancers. Galleri can detect these cancers because of the DNA it sheds into your bloodstream. That means it doesn't detect cancers that don't shed DNA into your bloodstream, like brain cancer. Galleri has a 0.5% false-positive rate, which means it's highly accurate. It finds 51.5% of cancers. And it's 89% effective in predicting where the cancer started'.[993]

Around a million people in the UK have dementia, mostly Alzheimer's. About a third of people born in the UK are likely to experience dementia in their lifetime, according to recent estimates. It is the main cause of death, but current drugs (which cost £34.7bn annually) only help symptoms and do not stop progression.[994] A 2019 analysis based on the Global Burden of Disease database predicted that the number of people with dementia would increase from 57.4m cases globally in 2019 to 152.8m cases in 2050. However, although dementia has been increasing globally, there is evidence that, when controlling for population aging, the prevalence has actually fallen in recent years. A 2020 study – led by Francine Grodstein, professor of internal medicine at the Rush Alzheimer's Disease Center in the US – that followed the health of around 50,000 over-65s found the incidence rate of new cases of dementia in Europe and North America had dropped 13% per decade over the past 25 years.

The reasons are not currently well understood, but some scientists have put it down to improved cardiovascular health (how effectively the body's arteries and veins carry blood to and from the heart) and especially the vascular health of the brain.[995] Professor Albert Hofman, chair of the department of epidemiology at the Harvard TH Chan School of Public Health, says that: 'In North America and in Western Europe, there has been for 50 years now an enormous emphasis on preventing cardiovascular diseases . . . that led to heart attacks and strokes', adding that a third of the population over 50 now takes pills to control high blood pressure and the use of statins to reduce cholesterol has soared. Carol Brayne, professor of public health medicine at the University of Cambridge and the lead investigator of the Cognitive Function and Ageing Studies, argues that reducing the

[993] https://health.clevelandclinic.org/the-galleri-test; https://www.bbc.co.uk/news/articles/c205g21n1zzo

[994] Sarah Knapton (2023) Alzheimer's could cause brain cells to kill themselves, *Daily Telegraph*, 15 September; https://www.telegraph.co.uk/news/2023/09/15/dementia-researchers-uncover-why-brain-cells-die/

[995] The US Centers for Disease Control and Prevention defines brain health as an ability to perform all the mental processes of cognition, including the ability to learn and judge, use language, and remember (What is a Healthy Brain? New Research Explores Perceptions of Cognitive Health Among Diverse Older Adults. Centers for Disease Control and Prevention: Healthy Aging; https://www.cdc.gov/aging/pdf/perceptions_of_cog_hlth_factsheet.pdf) and has established the Healthy Brain Initiative Road Map (Road Map for State and Local Public Health: Healthy Brain Initiative. Centers for Disease Control and Prevention: Alzheimer's Disease and Healthy Aging program; https://www.cdc.gov/aging/healthybrain/roadmap.htm).

incidence of dementia requires 'optimizing neurological function' throughout the course of a person's life by improving brain and physical health. A 13% decline would mean 15m fewer dementia cases by 2040 in high-income countries. Another important factor is 'cognitive reserve': people with more active brains are better able to delay the effects of dementia. Brayne found, using brain samples, that 'the higher the level of education, in terms of years of exposure, the less likely you were to express dementia during your lifetime'. Brayne also discovered that the fall in dementia cases was lower in deprived areas, suggesting that there was a social link between dementia and the quality of nutrition and housing. Responding to this finding, Dr Susan Mitchell, head of policy at Alzheimer's Research UK, said: 'with [the] increased prevalence of diabetes [and] obesity [which are] risk factors for dementia, we may see the incidence rates start to increase in the future'. As supporting evidence for this, a 2023 study published by *The Lancet Public Health*, indicated that dementia incidence decreased in England and Wales by 28.8% between 2002 and 2008, but increased again by 25.2% between 2008 and 2016.

A 2020 *Lancet* study found that about 40% of dementia was preventable if people improved their mid-life health. Jonathan Schott, professor of neurology at the Dementia Research Centre at UCL, argues that 'it may well be that the lowest hanging fruit in terms of preventing dementia, in the western world at least, has already been [reaped]. But considerable scope remains to improve things in more disadvantaged communities and in poorer countries. So there's still a huge amount to be done in the developing world where those vascular risk factors perhaps aren't being looked after as well'. Scientists now believe that preventive measures combined with new drugs is the best way of dealing with dementia.[996]

Professor Andrew Scott points out: 'The dominant cause of many noncommunicable diseases is age itself. This suggests that efforts to slow the aging process should play a more prominent role in treatments rather than targeting particular diseases, such as cancer. A growing research program is focusing on understanding why we age and developing treatments that, if successful, could lead to dramatic changes in the malleability of age'.[997]

Examples of these developments include:

- Periodic fasting or caloric restriction has been shown to be one of the most effective ways of preventing age-related disorders and promoting life expectancy and health span. The first study to examine caloric restriction in humans was the Comprehensive Assessment of Long-Term Effects of Reducing Intake of Energy (CALERIE) at Duke University.[998] It showed that two years of caloric restriction could slow biological aging and reduce age-related markers, such as oxidative stress.[999]

[996] Sarah Neville (2023) What is behind the unexpected decline in dementia?, *Financial Times*, 30 October; https://www.ft.com/content/184f6e81-d9ce-4a14-84f0-5190ea36e798.
[997] Andrew Scott (2020) The Long, Good Life: Longer, more productive lives will mean big changes to the old rules of aging, *Finance and Development*, March.
[998] https://calerie.duke.edu/
[999] Carla Heyworth (2020) Metabolic aging, fasting and metformin, *Longevity Technology*, 10 March;

- Diets and food supplements designed to treat age-related disorders. The Buck Institute's Dr Eric Verdin reports the development of fasting-mimicking diets. There are also caloric restriction mimetics, supplements that offer the health-promoting effects of fasting, without the need for fasting. Metformin (previously used in the treatment of type-2 diabetes) is being examined as a drug for increasing healthspan by Dr Nir Barzilai, Professor of Medicine and Genetics and Director of the Institute for Aging Research at the Albert Einstein College of Medicine in New York, in his TAME (Targeting Aging with Metformin) trial.[1000] Similarly, methionine, an amino acid that plays an important role in the metabolism, is being considered for the treatment of age-related disorders. Singapore-based Senescence Life Sciences aims to use nutraceuticals – ingredients and raw materials for dietary supplements – to combat natural brain aging by targeting an enzymatic process that has been shown to restore classical neuronal indicators of age – including learning, memory and decision-making performance.[1001] Food companies are promoting 'future food' which combines healthier eating and leveraging agricultural gene editing.[1002]
- Recognition that low concentrations of circulating 25-hydroxyvitamin D (25[OH]D), a metabolite used as a clinical indicator of vitamin D status, are associated with an increased risk of cardiovascular disease and all-cause mortality, as well as other chronic diseases.[1003]
- Developing a wearable device to detect early signs of Alzheimer's disease as part of the Early Detection of Neurodegenerative diseases (EDON) project run by Alzheimer's Research UK. EDON will analyze data from existing studies using artificial intelligence and use the results to design a prototype device within three years. The wearable will then collect data on gait, heart rate and sleep patterns etc which can be used to identify signs of the disease years before symptoms develop.[1004]
- Neural engineering to deal with destructive addictions, such as alcohol and drug dependency. Addictions and also neurological conditions like Parkinson's disease are linked to dopamine, the so-called pleasure chemical. Parkinson's gradually kills off dopamine-producing cells in the brain, but new therapeutic approaches involve replacing the lost dopamine. One example involves delivering the gene for the protein glial-derived neurotrophic factor (GDNF) into the brain, which then encourages dopamine production. Professor Krystof Bankiewicz from Ohio State University has published a study in *Nature Medicine* which assesses whether delivering GDNF to brain areas associated with addiction and reward through gene therapy could help reconfigure the dysfunctional brain pathways of alcoholics. The

https://www.longevity.technology/metabolic-aging-fasting-and-metformin/

[1000] Carla Heyworth (2020) Metabolic aging, fasting and metformin, *Longevity Technology*, 10 March; https://www.longevity.technology/metabolic-aging-fasting-and-metformin/

[1001] Danny Sullivan (2020) Nutraceuticals to beat cognitive decline before it starts, *Longevity Technology*, 16 March; https://www.longevity.technology/nutraceuticals-to-beat-cognitive-decline-before-it-starts

[1002] Aging Analytics Agency, *Advancing Financial Industry: Longevity/AgeTech /WealthTech*

[1003] https://www.labmedica.com/clinical-chem./articles/294790627/vitamin-d-deficiency-has-greater-risk-for-all-cause-mortality.html

[1004] Jane Wakefield (2020) Wearable to spot Alzheimer's being developed, *BBC News*, 13 February.

study involved macaque monkeys which, like humans, enjoy alcohol, but lost interest when given GDNF therapy. Bankiewicz said 'we have to view all brain disorders, such as addictions, through the lens of different wiring. The brain is incredible at organizing connections, but certain individuals are more predisposed to being wired in certain ways'. Re-engineering the brain to alter human behaviour is a new field in medicine and is a response to the ineffectiveness of traditional psychotherapies, such as cognitive behavioural therapy where 60% of patients with alcohol dependency relapse within a year. Research is now showing that addictions also have a genetic origin. Certain genes (and their mutations) in the brain, linked to impulsivity, can create innate urges when exposed to addictive substances. For example, the melanocortin 4 receptor (MC4R) gene senses fatness and a mutation causes some people's brain to believe they are less fat than they are, leading to overeating.

- Semaglutide-based weight-loss drugs, such as Wegovy (which is licensed as Ozempic for type-2 diabetes), deliver a synthetic version of the hormone GLP-1 (Glucagon-Like Peptide-1) which acts on the brain to create a sense of fullness. An Oxford University study found that Ozempic reduced the risk of Parkinson's disease and dementia by up to 48%, as well as the risk of developing the brain inflammation encephalitis.[1005] It could also be used to treat addictions, since it helped to reduce alcohol and nicotine use.[1006] A number of studies presented at the European Society of Cardiology Conference 2024 suggested that Ozempic could offer 'the fountain of youth' by turning back the clock on a number of diseases, in addition to Alzheimer's and Parkinson's, such as diabetes and cancer. These diseases have been linked to inflammation of the immune system which Ozempic helps to reduce. It could also control previously untreatable blood pressure, reverse kidney disease, and 'revolutionise cardiovascular care'. However, there could be side effects, such as nausea, bloating and gas.[1007] At the 2025 Ageing Research and Drug Discovery Conference in Copenhagen, Eli Lilly and Novo Nordisk, the main developers of GLP-1s, described them for the first time as 'longevity medicines'. Lotte Bjerre Knudsen, chief scientific adviser at Novo Nordisk, said that the longevity label was justified by the 'multi-faceted' effects of GLP-1s on organs throughout the body.[1008]
- There are also examples of non-invasive brain stimulation which avoid the potential side effects associated with pharmacological drugs. One is transcranial magnetic stimulation (TMS) which can help people stop smoking, according to a study published in *Nature Communications* and led by Professor Barbara Sahakian from the University of Cambridge. She said: 'In smoking, this area of the brain [the left

[1005] There is another ongoing study, called Evoke/Evoke+, which is investigating the use of semaglutide in people with early Alzheimer's disease and is sponsored by Novo Nordisk, the developer of Wegovy; https://www.alzheimer-europe.org/research/clinical-trials/evoke-0

[1006] https://www.telegraph.co.uk/news/2024/07/11/ozempic-could-cut-the-risk-of-dementia-by-half-oxford-study

[1007] https://www.telegraph.co.uk/news/2024/08/30/ozempic-offers-fountain-of-youth-studies-find; https://www.bbc.com/news/articles/ce81j919gdjo; https://www.telegraph.co.uk/news/2024/12/25/ozempic-could-help-patients-with-alzheimers/

[1008] https://www.ft.com/content/16d6269f-aedd-4779-86c4-13365e4f7ed9

ventromedial prefrontal cortex which is involved in willpower and feelings of pleasure] gets reduced, so then behaviour becomes disinhibited and that may be why smoking cigarettes can often lead on to marijuana and alcohol use. The hope might be that this reduction can be mitigated by transcranial stimulation, and thereby you could re-establish inhibitory control'. The aim of TMS is to adjust the brain's reward, motivation and decision-making circuits in a way which reduces the cravings. In a similar vein, a study published in *Current Psychology* by scientists at the University of Messina in Italy found that applying low-level electrical activity to areas of the prefrontal cortex, which influences social skills, could help limit aggression, impulsivity and promote empathy – and hence help to reintegrate those with antisocial personality disorders, such as criminals, back into society. These are all different approaches for adjusting the chemicals, hormones and networks in the brain to alter damaging behaviour. However, this raises ethical issues, as Professor Bankiewicz points out: 'I believe that these therapies will drive a permanent change in those who have incurable addictions. But would that predispose them to be more reckless, knowing that there is something available? It's a good question, and I don't know the answer. Perhaps in some people, maybe not in others'. There are also safety concerns when it comes to gene therapy, such as the possibility that it could lead to cancer, as well as the ethical issues associated with changing an individual's behaviour and personality, possibly permanently. Bankiewicz argues that such therapies require weighing up the risks and benefits, and they should only be considered for those with very severe addictions and where all other approaches have failed.[1009]

- The development of the Lenacapavir jab which protects against HIV for six months. The cost of the treatment exceeds $40,000 per annum, but it is hoped that this can be reduced to as little as $100.[1010]

Equally important are measures that contribute to later life wellness, which, in turn, are likely to increase both lifespan and healthspan. Examples include:

- Lifestyle medicine management. This has six pillars: restorative sleep, stress management and mental wellbeing, healthy eating, exercise, avoiding substance abuse, and healthy relationships. The most important of these is exercise (a minimum of three times a week for 20 minutes each, ideally outdoors in order to commune with Nature (i.e., biophilia)).[1011] But much more work needs to be done to understand the link to life expectancy, as Dr Verdin points out: 'How exactly does exercise impact longevity? We know it does, but we don't know what forms of exercise are effective – endurance vs high intensity interval training? 10,000

[1009] David Cox (2023) New research suggests neural engineering could spell the end of humanity's destructive addictions – but at what cost?, *Daily Telegraph*, 2 September; https://www.telegraph.co.uk/health-fitness/mind/brain-tweaking-addiction-transcranial-magnetic-stimulation/

[1010] https://www.telegraph.co.uk/global-health/science-and-disease/miracle-hiv-drug-lenacapavir-to-revolutionise-prevention

[1011] Noel McDermott, CEO of Mental Health Works; https://bslm.org.uk/lifestyle-medicine/what-is-lifestyle-medicine/

steps vs 4,000 steps? We need molecular-level data to increase our knowledge'.[1012,1013]

- Reducing non-adherence to medication. The World Health Organization has estimated that adherence to medication for chronic conditions is as low as 50% in developed countries and even lower in developing countries. The annual costs of medication non-adherence range from $100bn to $290bn in the USA, €125bn in Europe and AU$7bn in Australia. Around 10% of hospitalizations in older people are attributed to non-adherence. The typical non-adherent patient requires three extra medical visits per year, leading to increased treatment costs of $2,000 per annum. The International Longevity Centre (UK) said: 'We could see a considerable improvement in health outcomes (and consequently longevity), not only by developing new drugs, but by helping people adhere to existing treatment regimens that have already been researched, tested and prescribed for them'.[1014]
- The living environment. Where you live can have a significant impact on the likelihood that you will reach centenarian age, according a study from Washington State University's Elson S. Floyd College of Medicine. Washingtonians who live in highly walkable, mixed-age communities may be more likely to live to their 100th birthday. The study also found socioeconomic status to be correlated, and an additional analysis showed that geographic clusters where the probability of reaching centenarian age is high are located in urban areas and smaller towns with higher socioeconomic status. Existing research estimates that heritable factors such as genes only explain about 20% to 35% of an individual's chances of reaching centenarian age.[1015]
- Targeting products and services at older people with the intention of improving their wellbeing and indirectly their life and healthspans. Companies doing this are not being altruistic. Rather they recognize the financial resources available to this demographic in developed countries. In the US, for example, people over 50 control 75% of net wealth and 50% of disposable income and will spend around $4trn over the next twenty years. Tech companies like Amazon, Apple and Google are looking at designing new products and services for this group. Agetech[1016] in the form of digital health platforms and telemedicine is providing access to cost-effective

[1012] Interview in *Longevity Trends 2020*, published by Longevity Leaders, January 2020.
[1013] A variation of this is the ReCODE (reversal of cognitive decline) Protocol proposed by Dr Dale Bredesen. This involves increasing brainspan by eating healthy high-fibre foods and avoiding: ultra-processed food, obesity, poor oral health, viruses and inflammation, stress, and toxins. It also involves increasing neuroplasticity – the brain's ability to change and adapt due to experience – by regular flexing in the form of a small new daily cognitive challenge, a medium new monthly cognitive challenge and a large new annual cognitive challenge. See: Dale Bredesen (2025) *The Ageless Brain: How to Sharpen and Protect Your Mind for a Lifetime*, Ebury Publishing , London.
[1014] https://ilcuk.org.uk/doctors-orders/
[1015] Centenarian study suggests living environment may be key to longevity, Washington State University, 17 June 2020; https://news.wsu.edu/2020/06/17/centenarian-study-suggests-living-environment-may-key-longevity/
[1016] Defined as the digital-enabled market of consumers over 50. It relies on this age group being willing and able to access the market digitally.

healthcare, in combination with medical software and apps.[1017] Agetech also targets other aspects of wellbeing, such as education and financial wellness.[1018]

- The promotion of a 'positive outlook' to reduce memory decline. A study finds that people who feel enthusiastic and cheerful – what psychologists call 'positive affect' – are less likely to experience memory decline as they age, controlling for age, gender, education, depression, negative affect, and extraversion. This result adds to a growing body of research on positive affect's role in healthy aging.[1019]
- In 2023, Peter Attia MD published 'Outlive: The Science & Art of Longevity', which explores the science of not just prolonging life, but also prolonging aliveness. The book is described as a 'groundbreaking manifesto on living better and longer that challenges the conventional medical thinking on aging and reveals a new approach to preventing chronic disease and extending long-term health'. Attia argues that mainstream medicine has failed to make much progress against the diseases of aging that kill most people: heart disease, cancer, Alzheimer's disease, and type 2 diabetes. Too often, it intervenes with treatments too late to help, prolonging lifespan at the expense of healthspan, or quality of life. He recommends that we must replace this outdated framework with a personalized, proactive strategy for longevity, one where we take action now, rather than waiting.

These developments led Bank of America to conclude that the human lifespan could soon pass 100 years for significantly more people than historically,[1020,1021] with one of the

---

[1017] Angela Tyrrell (2020) Eight sectors to be disrupted by longevity, *Longevity Trends 2020*, published by Longevity Leaders, January 2020.

[1018] Angela Tyrrell, SVP, Longevity Leaders, identifies ten consumer trends driving the preventative wellness market: 1) digital tracking tools (e.g., for counting steps, logging calories, tracking ovulation or recording sleep patterns), 2) consumer biological testing (e.g., personalized DNA testing to improve lifetime health management), 3) personalization (of, e.g., nutrition and skincare), 4) responding to climate change (e.g., by driving less and walking or cycling more), 5) meat alternatives, 6) alcohol alternatives, 7) natural products (without preservatives, sugar and salt), 8) mental health awareness (leading to diagnoses and treatments that reduce cognitive decline in later life), 9) meditation and mindfulness programs (to reduce stress, improve sleep quality or breathing, or accompany a physical activity such as yoga), and 10) Ethical leadership (e.g., via a corporate and social responsibility policy that enhances a company's reputation with its customers and, as a consequence, has long-term benefits for the health of its employees). See *Longevity Trends 2020*, published by Longevity Leaders, January 2020.

[1019] Emily F. Hittner, Jacquelyn E. Stephens, Nicholas A. Turiano, Denis Gerstorf, Margie E. Lachman, Claudia M. Haase (2020**).** Positive Affect Is Associated With Less Memory Decline: Evidence From a 9-Year Longitudinal Study, *Psychological Science*, 31(11), 1386-1395.

[1020] Centenarians make up around 0.03% of the population in both the UK and US, but as the *Economist* conjectures: 'Living to 100 today is not unheard of, but is still rare. …Should the latest efforts to prolong life reach their potential, living to see your 100th birthday could become the norm; making it to 120 could become a perfectly reasonable aspiration'; https://www.economist.com/leaders/2023/09/28/living-to-120-is-becoming-an-imaginable-prospect. The population of centenarians is projected to rise from around 722,000 in 2024 to nearly 4 million by 2054. US centenarians are projected to rise from 101,000 in 2024 to approximately 422,000 over the same period; https://ceoworld.biz/2026/03/31/the-global-centenarian-surge-how-4-million-people-over-100-will-reshape-markets-and-policy/

[1021] Lynda Gratton and Andrew J. Scott's book *The 100-Year Life* provides a 'raft of solutions, showing how to rethink your finances, your education, your career and your relationships and create a fulfilling 100-year life', including:

biggest investment opportunities over the next decade being in companies working to delay human death, a market expected to be worth at least $600bn by 2025.[1022] To illustrate, in June 2021, M&G Investments launched the Better Health Solutions fund which will invest in companies whose products or services are designed to promote better health and wellbeing.[1023] Investment in the biotech and life sciences sector reached $5.2bn globally according to analysts at Longevity.Technology, with 130 deals in 2022.[1024] This compares with $6.2bn (190 deals) in 2021 and $3.0bn (148 deals) in 2020. The largest investment in 2022 was Jeff Bezos's $3bn financing for Altos Labs in California which focuses on cellular reprogramming in order to prolong youth.[1025] The Hevolution Foundation was also established. This is a Saudi-backed non-profit organization with an annual budget of up to $1bn to spend on 'independent research and entrepreneurship in the emerging field of healthspan science'.[1026] The leading longevity domains are 'Longevity discovery platforms', 'Longevity drugs', renewal therapies ('Regeneration', 'Rejuvenation', 'Cellular reprogramming') and 'Gene therapies'.[1027]

In order to take advantage of this increase in human lifespan, companies should exploit the longevity dividend, i.e., recognize the value of their older workforce and do not force them into retirement before they are ready to leave. Forced early retirement can have the effect of harming health and reducing life expectancy because of depression and loss of self-worth which can, in turn, lead to alcoholism, excessive drug use and suicide.[1028] Mercer's Next Stage research program, for example, showed that age and experience enhance

---

- How can you fashion a career and life path that defines you and your values and creates a shifting balance between work and leisure?
- What are the most effective ways of boosting your physical and mental health over a longer and more dynamic lifespan?
- How can you make the most of your intangible assets – such as family and friends – as you build a productive, longer life?
- In a multiple-stage life how can you learn to make the transitions that will be so crucial and experiment with new ways of living, working and learning?

The book is 'also fundamentally a call to action for individuals, politicians, firms and governments and offers the clearest demonstration that a 100-year life can be a wonderful and inspiring one' (Gratton and Scott (2016)). A subsequent book, Scott (2024), continues with this theme: 'Our longer lives can be a source of hope and fulfilment if we seize the opportunity to pursue the evergreen agenda, one in which we pursue a sustainable lifestyle both for ourselves as individuals – investing in our finances, health, skills and relationships to support a longer life – and for the planet'.

[1022] https://www.cnbc.com/2019/05/08/techs-next-big-disruption-could-be-delaying-death.html

[1023] https://www.professionaladviser.com/news/4033150/unveils-impact-fund-focusing-health-wellbeing

[1024] https://longevity.technology/news/global-longevity-investment-hit-5-2-billion-in-2022/

[1025] Other start-ups include Retro Biosciences, Human Longevity, InSilico Medicine, Juvenescence, NewLimit, Loyal, Centenara Labs, Calico Life Sciences and Cambrian Biopharma; https://www.ft.com/content/16d6269f-aedd-4779-86c4-13365e4f7ed9

[1026] https://longevity.technology/news/hevolution-ceo-on-how-to-spend-1-billion-a-year-on-longevity/

[10271027] https://longevity.technology/investment/report/annual-longevity-investment-report/

[1028] There is some evidence for this in the US. See, for example, Kate W. Strully (2009) Job Loss and Health in the U.S. Labor Market, *Demography*, 46(2): 221–246; Clemens Noelke and Jason Beckfield (2014) Recessions, Job Loss, and Mortality Among Older US Adults, *Am J Public Health*, 104(11): e126–e134; and Anne Case and Angus Deaton (2015) Rising Morbidity and Mortality in Midlife Among White Non-Hispanic Americans in the 21st Century, *Proceedings of the National Academy of Sciences of the United States of America*, December 8, 2015 112 (49) 15078-15083.

business performance. Companies that use data analytics and business impact modelling to examine their own organizational demographic data have discovered some key drivers of business performance. To illustrate:

- Experienced workers lower costs because they – and the people they supervise – are less likely to leave. A 5% reduction in turnover saved one of Mercer's clients $66m in cost per unit.
- Experienced workers increase productivity. Branch revenue at one US bank increased by $40m per year for each year of extra service/age of its sales team.

An important aspect of this is life-long learning in order to increase later-life productivity. This is being promoted, for example, as part of a project called 'Living, Learning and Earning Longer'[1029] by the OECD, the World Economic Forum, and the American Association of Retired Persons (AARP). Another aspect of the longevity dividend to companies from their employees working longer is potentially lower pension liabilities since additional pensions contributions are made and the pension, when it is paid, is drawn for a shorter period on average.[1030] Society also benefits from the increase in healthspan associated with the longevity dividend as a result of lower later-life healthcare costs.[1031]

Another important aspect is financial wellbeing. The US Consumer Financial Protection Bureau argues that: 'A person's financial wellbeing comes from their sense of financial security and freedom of choice – both in the present and when considering the future. …[A]dults' financial wellbeing [is influenced by]: income and employment; savings and safety nets; past financial experiences; and financial behaviours, skills, and attitudes'.[1032] A survey by WTW found that following the pandemic, employers in the UK had become more concerned about the financial wellbeing of their employees, with 80% saying that they were planning to introduce a financial wellbeing strategy. In addition to retirement savings, this could cover debt solutions, emergency savings and saving for housing. The main reasons given were that it supported broader welfare initiatives (including employee health), it enhanced employee benefits at a time of acute labour shortages, and it recognized employer duty of care.[1033] Pension schemes have also begun to offer financial wellness services to their members. On example in the UK is the Royal Mail Defined Contribution Pension Scheme which has chosen Destination Retirement from HUB Financial Solutions as a service to support scheme members making key financial choices in the run-up to retirement and beyond.[1034]

---

[1029] https://www.aarpinternational.org/initiatives/future-of-work/living-learning-and-earning-longer
[1030] Yvonne Sonsino, Global Co-Leader of Next Stage, Mercer, interviewed in *Longevity Trends 2020*, published by Longevity Leaders, January 2020.
[1031] For a typical individual, around 70% lifetime healthcare costs occur in the last 3 years of their life. This is the sum of 47.1% for long-term care costs (average across 5 countries: Denmark, Germany, Netherlands, Taiwan and US) and 22.9% for hospital costs (average across 9 countries: Denmark, Germany, Netherlands, Taiwan, US, England, France, Japan and Quebec). See: Eric B. French et al. (2017) End-of-Life Medical Spending in Last Twelve Months of Life is Lower than Previously Reported, *Health Affairs*, 36(7): *Advanced Illness & End-Of-Life Care*; https://doi.org/10.1377/hlthaff.2017.0174
[1032] https://www.consumerfinance.gov/data-research/financial-well-being-survey-data/
[1033] https://www.wtwco.com/en-GB/Insights/2021/05/future-of-financial-wellbeing-survey-2021
[1034] https://www.ipe.com/news/uk-roundup-house-of-fraser-plan-strikes-600m-buyout/10060379.article

A 2022 report[1035] from the Geneva Association and the Global Aging Institute, while accepting that ensuring financial wellbeing was the core purpose of life insurance, argued that 'traditional business models have come under stress as socio-economic, demographic, health and technological developments, [and] combined with a protracted period of low interest rates, have dented the appeal of savings-oriented life insurance globally'. To counteract this, the report made four recommendations for insurers:

- *Step up efforts to directly affect the determinants of savings and risk protection.* Inherent in the concept of financial wellbeing is an ecosystem of consumer needs that transcends the traditional products offered by life insurers. If life insurers wish to position themselves more strategically, they will have to redefine their role to include directly affecting the determinants of retirement savings and risk protection through pathways such as education, advisory services, mentoring and financial incentives in partnership with government, financial advisers and wealth and asset managers. Doing so will require insurers to either create or buy new capabilities, or else partner to bring them in.
- *Promote financial literacy in young age.* The lack of attention to financial education leaves the young ill-prepared to navigate the insecurities of the current labour market and successfully prepare for their eventual retirement. It also overlooks the opportunity to cement the role of life insurance at an early age. With a relatively modest investment, insurers can partner with national educational agencies, schools, communities and digital platforms to develop innovative ways of propagating financial knowledge, including by gamifying it, using social media and leveraging word of mouth and 'influencers'.
- *Improve risk exposure through preventive measures.* Very few life insurers cited limiting risk exposure as a primary motivation for developing new financial wellbeing products. Yet there are strong connections between financial wellbeing, general wellbeing and risky behaviours. Altering these behaviours will require insurers to embed data science at the heart of their products and indeed to see it as a key to understanding needs, shifting the paradigm from repair/replace to predict/prevent. Similarly, using data science to better integrate health and wellness products could have significant benefits.
- *Tap into the longevity economy.*[1036] Life insurers' efforts to tap into the burgeoning longevity sector are currently modest. There is also little to suggest that their products address changing retirement patterns, such as unretirement, phased retirement and new careers post-retirement, or changing family structures, including shifts in multigenerational living arrangements. New solutions such as

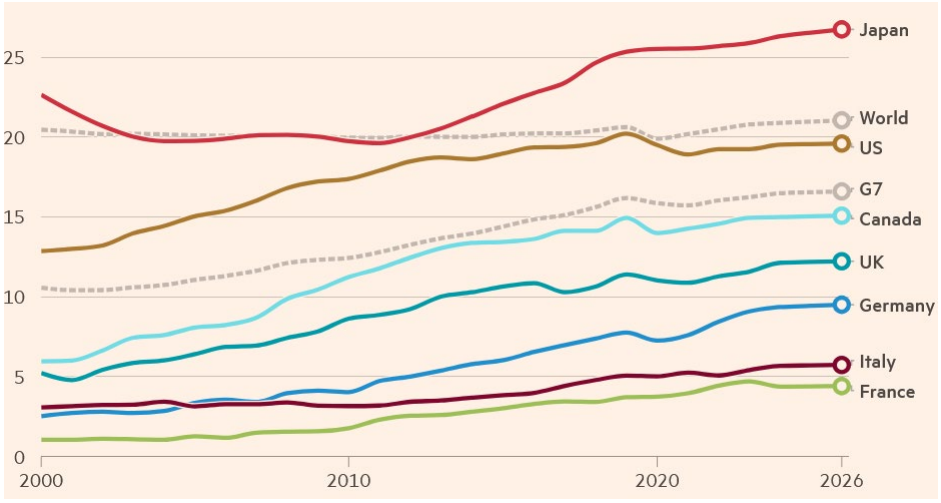
[1035] Financial Wellbeing: Is it the key to reinventing life insurance?, May 2022; https://www.genevaassociation.org/financial-wellbeing-report

[1036] This is generally defined as the economic activities of people aged 50 years and over. In the US, four generations are currently involved: the GI Generation (1901-1926), the Silent Generation (1927-1945), the Baby Boomers (1946-1964) and Generation X (1965-1980); https://www.pensionpolicyinternational.com/us-what-the-longevity-economy-means-and-why-its-important/. See also Joseph F. Coughlin (2017) *The Longevity Economy: Unlocking the World's Fastest-Growing, Most Misunderstood Market*, PublicAffairs. Coughlin director of the Massachusetts Institute of Technology AgeLab.

silver sabbaticals to enable middle-aged adults to re-skill and to encourage longer working lives as well as supplementary health and care benefits that take over where government leaves off could help insurers unlock the potential of the silver economy and increase their relevance to aging societies.

Figure 10 shows that people are working longer in their lives. Professor Ian Goldin of Oxford University said: 'People will need to work longer, [but many ageing people in good health] will want to work longer because work gives us meaning, it gives us networks, it gives us a sense of self-worth, and it gives us skills'.[1037]

**Figure 10: Share of labour force participation rates by people aged 65+ (%)**




Source: ILO, Valentina Romei (2026) Five ways demographics are transforming the world economy, *Financial Times*, 6 March; https://www.ft.com/content/152766ba-072d-4f5d-948e-d60f93e406d1

The silver economy focuses on goods and services for older adults. In October 2024, a study by Technopolis Group and Oxford Economics predicted that the silver economy would contribute €6.4trn to the EU's GDP by 2025 and support 88 million jobs. The key growth areas are healthcare (including telemedicine, smart home technologies, and care services), technology, leisure and tourism. Some fund managers are promoting funds linked to healthcare, mobility, and assisted living to deal with the capital needs of ageing societies. The funds are targeted at younger investors to build long-term wealth while contributing to systemic resilience.[1038]

Broader than the silver economy is the longevity economy which recognises the potential for older adults to be active contributors to society, as well as consumers. One way of doing this is to enhance the digital skills of seniors, as is happening in Slovakia, for

[1037] https://www.ft.com/content/152766ba-072d-4f5d-948e-d60f93e406d1
[1038] https://funds-europe.com/op-ed-silver-to-self-reliant-investing-across-generations

example: 'New technologies contribute to slowing down aging, improving cognitive functions, and strengthening memory', according to Slovak Minister, Richard Rasi.[1039]

In January 2024, the World Economic Forum introduced six Longevity Economy Principles with the aim of seizing the opportunities associated with a new era of longevity and generational rebalancing as well as navigating the challenges ahead:[1040]

1. Financial Resilience Across Key Life Events: Life is unpredictable. From career breaks to unexpected health issues, financial resilience is crucial. The WEF advocates for robust social safety nets and innovative financial products to help individuals navigate these challenges. This requires collaboration between public policies and private sector innovations to prevent financial hardship and promote stability.
2. Embedding Financial Literacy: The WEF says only a third of people globally could be described as financially literate. This contributes to inequalities not just in wealth but also in life expectancy. Knowledge is power, especially when it comes to managing finances. The WEF emphasizes the need for universal access to financial education. By improving financial literacy, individuals can make informed decisions that enhance their economic security and overall well-being.
3. Prioritizing Prevention for Healthy Aging: A longer life should also mean a healthier life. The principles advocate for shifting the focus of healthcare towards prevention and equitable access to medical services. By promoting health maintenance over disease treatment, societies can ensure that people not only live longer but also enjoy a better quality of life
4. Evolving Jobs and Enabling Lifelong Skill Building: A quarter of people aged 55 and older want to work in old age, but face barriers in finding opportunities. In a world where careers are spanning ever-lengthening decades, companies will want to integrate this workforce. Allowing people to work beyond retirement ages and facilitating return to work after career breaks. Continuous learning will become the essential means to enable this. The WEF calls for both job structures and educational systems to adapt. Lifelong learning and skill development must become more continuous, enabling older workers to remain engaged and productive – at every age and stage.
5. Designing In Social Connection and Purpose: Social isolation is a growing concern in aging populations. The principles highlight the importance of fostering environments that promote social connections and a sense of purpose. This approach is vital for mental and physical health, ensuring that individuals feel valued and engaged in their communities.
6. Addressing Longevity Inequalities: Inequalities in aging, whether based on gender, race, or class, must be addressed. The WEF advocates for targeted actions to reduce

[1039] https://www.pensionpolicyinternational.com/from-ageing-to-active-living-working-through-old-age-in-eu/

[1040] *Longevity Economy Principles: The Foundation for a Financially Resilient Future*; https://www.weforum.org/publications/longevity-economy-principles-the-foundation-for-a-financially-resilient-future/; https://initiatives.weforum.org/financial-resilience-for-every-generation/home

these disparities, ensuring that the benefits of longer life spans are accessible to everyone.

In November 2025, Pictet Asset Management launched Pictet-Longevity, a fund targeting investment opportunities arising from global demographic ageing. The fund will invest in companies improving healthspan, such as those offering effective, scalable health solutions that extend healthy living. It will also invest in companies providing tech-driven tools that enhance workplace efficiency as the global workforce contracts.[1041]

There have also been significant negative developments. Examples include:

- An increase in deaths from heart and circulatory diseases in the UK for the first time in 50 years – as a result of an increase in obesity and type-2 diabetes.[1042] However, recent research has shown that taking the weight loss drug Wegovy (Ozempic) for at least three years cuts the risk of heart attack, stroke and cardiac death by 20%.[1043]
- Deaths of despair. The 'longevity economy' has not benefited older workers in jobs with low, unstable incomes without employee benefits. Such workers typically accumulate little wealth and savings over their working lives and face a retirement of poverty.[1044]
- Increasing antibiotic resistance. The World Health Organization points out that a growing number of infections – such as pneumonia, tuberculosis, gonorrhoea, and salmonellosis – are becoming harder to treat as the antibiotics used to treat them become less effective. Antibiotic resistance occurs naturally, but misuse of antibiotics in humans and animals is accelerating the process. It is one of the biggest threats to global health, food security, and development. It leads to longer hospital stays, higher medical costs and increased mortality.[1045] To illustrate, resistance rates to macrolide, an antibiotic used to treat pneumonia, is as high as 90% in parts of Asia; and this has been associated with an increase in child pneumonia cases in China which has spread to Europe.[1046]
- The return of illnesses that had been eradicated. For example, the UK has been polio-free since 2003, with the last wild case detected in 1984. However, a polio virus mutation was detected in sewage system in London in early 2022, with tests indicating that it had been imported from a country where polio was still

[1041] https://funds-europe.com/pictet-launches-fund-to-capture-growth-from-ageing-societies/
[1042] Haroon Siddique (2019) UK heart disease fatalities rise for first time in 50 years, *Guardian*, 13 May.
[1043] https://www.telegraph.co.uk/news/2024/05/13/weight-loss-jabs-cut-risk-of-heart-death-by-a-fifth
[1044] U.S. Deaths of despair - Not everyone benefits from the 'longevity economy', *Pension Policy International*, 14 October 2020; https://pensionpolicyinternational.com/us-deaths-of-despair-not-everyone-benefits-from-the-longevity-economy/
[1045] Antibiotic resistance, World Health Organization, 5 February 2018; https://www.who.int/news-room/fact-sheets/detail/antibiotic-resistance
[1046] https://www.telegraph.co.uk/global-health/science-and-disease/child-pneumonia-europe-france-ireland-denmark-netherlands

present.[1047] In July 2022, a case of polio was reported in New York state, the first in the US since 1993; again, it is believed that the person caught it from someone outside of the US.

- The development and spread of new viruses. For example, the Ebola virus was first discovered in 1976. There was a major outbreak in West Africa in 2014–2016 and in Uganda in 2022.[1048]
- Long Covid. Michael Fasano (2023)[1049] points out that 'Most patients totally recover from acute Covid within 3 to 4 weeks after onset of infection. Long Covid has been reported in 10% to 30% of those with Covid-19,[1050]and in some studies, even more. It is more common in women, non-whites, hospitalized patients and those with a chronic obstructive pulmonary disease and/or smoking history. The World Health Organization characterizes Long Covid, or Post Covid-19 Syndrome, as being associated with:
    - Individuals with a history of probable or confirmed SARS-CoV-2 infection (the virus that causes Covid-19) who experience symptoms impacting everyday life, such as fatigue, shortness of breath and cognitive dysfunction; and
    - Symptoms that usually are present 3 months from the onset of acute Covid-19, that last for at least 2 months and can't be explained by an alternative diagnosis. … Approximately 25% of Americans with long Covid report significant activity limitations'.[1051]
- Covid reinfection risk. There is currently conflicting evidence. On the one hand, Michael Fasano (2023)[1052] considers a number of studies which show that 'those infected more than once with SARS-CoV-2 have a higher risk of experiencing diseases associated with Long Covid. …However, the severity of the reinfection related impairments is less than that associated with primary infection'. On the other hand, a study published in *Nature Medicine* by Washington University researchers found that people who caught Covid more than once were twice as likely to die and three times more likely to be hospitalized than people only infected once. They were also likely to experience more damage to their lungs, heart, brain, blood, muscles and digestive system. The study was based on data from 500,000 US veterans.[1053]

Yet even here, there have been some potentially positive developments. For example, scientists at the University of Exeter have developed a technique which can be used to assess whether a bacterium is likely to respond to antibiotics. It works by examining whether the fluorescent qualities of the antibiotics are taken up by bacteria. If so, the bacteria glow brighter under the microscope, revealing that the antibiotic has infiltrated the

[1047] https://www.telegraph.co.uk/news/2022/06/22/polio-back-national-incident-declared-uk-disease-spreads-first
[1048] https://www.who.int/health-topics/ebola#tab=tab_1
[1049] Michael Fasano (2023) Long COVID and Reinfection Risk, *Fasano eNewsletter*, February.
[1050] Nashville Chest, October 16-19, 2022.
[1051] CDC Survey, September 14-26, 2022.
[1052] Michael Fasano (2023) Long COVID and Reinfection Risk, Fasano eNewsletter, February.
[1053] https://www.telegraph.co.uk/news/2022/11/10/catching-covid-doubles-risk-death

membrane and could be effective. The research could contribute to efforts to reduce prescribing, and also enable the development of more effective antibiotics, to help fight the global threat of antibiotic resistance.[1054] Similarly, Roche is developing zosurabalpin, the first new antibiotic in 50 years. It is designed to treat the drug-resistant bacteria Acinetobacter baumannii which affects patients who are in the hospital, causing infections such as pneumonia and sepsis.[1055] However, in October 2025, the World Health Organization warned that new antibiotics were not being developed quickly enough to keep pace with the rapid spread of superbugs. There were 90 treatments in the clinical pipeline, but only 15 were considered 'innovative' in the sense of involving entirely new drugs or therapies. WHO said: 'The pipeline faces a dual crisis: scarcity and lack of innovation'.[1056] WHO also warned that one in six bacterial infections worldwide were now resistant to common antibiotics, with bacterial illnesses like urinary tract infections and sexually transmitted diseases becoming increasingly difficult to treat. It found that common antibiotics such as oral penicillin and ciprofloxacin had become around 40% less effective between 2018 and 2023.[1057]

Dr Nir Barzilai argues that 'Death is inevitable but aging is not'.[1058] This is a key message that needs to be taken into account when quantifying longevity risk and projecting healthy life expectancy going forward. There are also clear implications for the PRT market. For example, Club Vita's Erik Pickett conjectures that 'If we assume that [GLP-1] treatments could help around a third of the population manage their weight from obesity into the healthy range, life expectancy could increase by around 1-2 years for 50-59 year-olds and 0.33-1.33 years for 60-69 year-olds. This could equate to an increase in liabilities for a pension plan or pension risk transfer portfolio of around 4%. To put this into perspective, in the UK, statins (one of the major success stories in public health over the last 30 years) have been estimated to have increased national life expectancy at age 70 by 2-3 years between 1987 and 2010'.[1059]

### *Artificial intelligence, machine learning, robotics and quantum computing*

There have been a number of significant developments:

- Combining natural-language processing (NLP) and other artificial intelligence (AI) could reveal clinical insights buried in existing medical records and scans.[1060]

[1054] Glowing bacteria to help tackle antibiotic resistance, Open Access Government, 3 July 2020; https://www.openaccessgovernment.org/glowing-bacteria/89771/
[1055] https://www.telegraph.co.uk/news/2025/05/26/first-new-antibiotic-in-50-years-to-tackle-superbug/
[1056] Global Health Bulletin Telegraph World, 3 October 2025
[1057] https://www.telegraph.co.uk/global-health/science-and-disease/one-in-six-bacterial-infections-now-drug-resistant/
[1058] Amelia Hill (2019) Scientists harness AI to reverse aging in billion-dollar industry, *Guardian*, 21 December; https://www.theguardian.com/science/2019/dec/21/scientists-harness-ai-to-reverse-ageing-in-billion-dollar-industry
[1059] https://www.clubvita.net/us/news-and-insights/vitamins-health-glp-1-obesity-medications-will-they-be-as-big-as-statins-for-life-expectancy
[1060] Investment Week (2022) Healthcare is on the cusp of a digital revolution, 30 November.

- Using AI for many health-related purposes, such as the early detection of heart disease and breast, lung and prostate cancer,[1061] diagnosis of leukemia, reading retinal scans with as much accuracy as experienced junior doctors (using Google's DeepMind), the use of minimally invasive procedures in hospitals to improve the quality of patient care, correcting faults in the human nervous system (e.g., robotic arms controlled by brain signals replacing lost human arms) and reducing false results in Covid-19 lateral flow tests.[1062]
- The development of an AI tool called AlphaFold (by DeepMind) which has predicted the structure of almost (98.5% of) the entire human proteome (the full complement of proteins expressed by an organism). Proteins underpin every biological process. They are made from long chains of amino acids and each has a unique complex 3D structure. In 2020, AlphaFold was able to predict protein structures in minutes and to a remarkable degree of accuracy. This helped researchers understand what individual proteins do and how they interact with other molecules.[1063]
- AI has designed proteins with anti-microbial properties which could be incorporated into new medicines.[1064]
- Researchers at Leipzig University are using AI to analyze the genetic structures of pathogens from 10 high-risk viral families that have the potential to mutate and trigger a pandemic. It will then help to develop a new generation of vaccines capable of protecting against the outbreak of a novel pathogen – known as 'Disease X'.[1065]
- Using big data and AI to improve and enhance longevity, as a result of, e.g., preventative medicine (such as spotting cancers in scans), accelerating drug discovery, establishing new genetic connections, improving operational efficiency in health delivery.[1066] Using microchips to repair motor function in human organs. Elon Musk set up Neuralink in 2016 to explore how to connect the human brain to a computer using the N1 microchip (or 'brain-computer interface'). Musk

---

[1061] https://www.labmedica.com/molecular-diagnostics/articles/294797129/new-diagnostic-approach-combines-dna-testing-with-ai-analysis-for-coronary-heart-disease-risk-assessment.html; https://www.nytimes.com/2023/03/05/technology/artificial-intelligence-breast-cancer-detection.html; https://www.labmedica.com/pathology/articles/294796508/ai-powered-prostate-cancer-diagnosis-tool-accurately-identifies-and-classifies-tumors.html; https://www.labmedica.com/molecular-diagnostics/articles/294806843/index.php

[1062] Christine Chow (2020) Artificial intelligence in healthcare, Investment Week, 4 December; https://www.investmentweek.co.uk/feature/4023966/artificial-intelligence-in-healthcare-the-do-no-harm-ethos-must-be-extended-to-its-application-in-the-sector/. Startups.co.uk Newsletter, 30 June 2019; https://www.labmedica.com/industry/articles/294787904/artificial-intelligence-ai-in-medical-diagnostics-market-to-reach-usd-386-billion-by-2025.html; https://www.labmedica.com/hematology/articles/294789897/artificial-intelligence-helps-diagnose-leukemia.html; https://www.labmedica.com/covid-19/articles/294795002/ai-takes-guesswork-out-of-lateral-flow-testing.html

[1063] https://deepmind.google/science/alphafold/; https://www.nature.com/articles/d41586-021-02025-4

[10641064] https://www.newscientist.com/article/2356597-ai-has-designed-bacteria-killing-proteins-from-scratch-and-they-work/

[1065] https://www.telegraph.co.uk/global-health/science-and-disease/scientists-ai-artificial-intelligence-vaccine-disease-x

[1066] Risk of Living Longer Series, Session 5, ClubVita webinar, 9 July 2024.

claims the N1 microchip can repair motor function in the paralysed, restore eyesight and hearing and help those suffering from memory loss through dementia and Alzheimer's. The technology could also allow humans to compete with AI by controlling machines with the power of thought. The N1 microchip is a 4mm square. Each person could have up to 4 implanted in the skull. Attached to the chip are superfine wires. They are placed close to important parts of the brain, recording neuron impulses. The chips connect wirelessly to a device behind the ear containing a Bluetooth radio. This sends signals to control a smartphone or computer. In January 2024, the first experiment using a human began when a patient had the chip inserted under their skull with the aim of sending instructions to the chip using thoughts alone. Neuralink's first successful product would be named 'Telepathy'.[1067] In March 2024, it was reported that a 29-year-old patient, paralyzed below the shoulders after a diving accident, was able to play chess on his laptop and move the cursor using his thoughts transmitted via Neuralink.[1068]

- Deep brain stimulation combined with improved mapping of the nerve networks in the brain that have become dysfunctional in four neurological disorders – Parkinson's disease, dystonia, Tourette's syndrome and obsessive-compulsive disorder (OCD) – has resulted in substantial improvement in symptoms. A deep brain stimulator acts like a pacemaker for the brain. It has two electrodes that are implanted near the brain's subthalamic nucleus and the settings are adjusted through a pulse generator implanted under the skin of the chest. The device has also been used to help stroke survivors regain their independence.[1069]
- The development of a non-invasive blood test to assess the likelihood of someone developing Alzheimer's up to two decades before any symptoms appear. The test is the result of combing nanotechnology and AI to analyze proteins in the blood for early indicators (biomarkers) of neurodegeneration. Previously, identifying proteins with early neurodegeneration markers was like looking for a needle in a haystack. But the new test involves an ultra-thin silicon chip embedded with nanopores (tiny nanometer-sized holes). A blood sample is placed on the silicon chip that is then inserted into a handheld device which employs an AI algorithm to search through the blood sample for protein markers indicative of early-stage Alzheimer's.[1070]
- Diagnosis of long COVID in children using an AI-driven blood test.[1071]
- The launch of the miLab AI-based electro-dynamic blood and cancer diagnostic platform. It performs diagnostic processes, such as staining, digital imaging, and

[1067] Emin Shinmaz (2020) Could Musk 's microchip really boost brainpower, *Daily Mail*, 29 August; Matthew Field (2024) Nine ways Elon Musk's brain implant could change the world, *Daily Telegraph*, 31 January, https://www.telegraph.co.uk/news/2024/01/31/elon-musk-implant-neuralink-brain-epilepsy-neuroscience

[1068] https://www.theguardian.com/technology/2024/mar/20/elon-musk-neuralink-brain-chip-patient-chess

[1069] https://edition.cnn.com/2024/03/15/health/deep-brain-stimulation-ocd-study-wellness/index.html; https://edition.cnn.com/2023/08/14/health/deep-brain-stimulation-stroke

[1070] https://www.labmedica.com/molecular-diagnostics/articles/294798677/cheap-non-invasive-blood-test-predicts-alzheimers-risk-20-years-ahead-of-symptoms.html

[1071] https://www.labmedica.com/molecular-diagnostics/articles/294803860/ai-driven-blood-test-to-revolutionize-diagnosis-of-long-covid-in-children.html

AI analysis, e.g., on cervical cells, thereby contributing to the early diagnosis of cervical cancer, the fourth largest cancer type for women.[1072]

- Gestalt Diagnostics has released the Mitotic Counting AI algorithm which can help to identify the eight types of cancer – cutaneous mast cell tumors, breast cancer, lymphoma, lung cancer, melanoma, neuroendocrine, colon cancer, and bladder carcinoma – across seven scanner models – including Hamamatsu, Leica, 3D Histech and Aperio. Key to the broad applicability of deep learning algorithms is their ability to adapt to new scanners and different types of tissue – a very broad dataset is needed to do this.[1073]
- Paige and Microsoft are collaborating to revolutionize cancer diagnosis and treatment by creating the world's largest image-based AI models in the fields of digital pathology and oncology. Building on Paige's Large Foundation Model, which contains around a billion images from half a million pathology slides covering various types of cancer, the new AI model will have billions of parameters and leverage Microsoft's advanced supercomputing capabilities. It aims to capture the full complexities of cancer and is intended to be the cornerstone for future clinical tools and computational biomarkers in oncology and pathology. The model will be accessible to hospitals and labs worldwide via Microsoft's Azure platform. Desney Tan, vice president and managing director of Microsoft Health Futures, said 'Unleashing the power of [generative] AI[1074] is a game changer in advancing healthcare to improve lives'.[1075]
- Lunit (Seoul, South Korea) has developed the Universal Immunohistochemistry (uIHC) AI model to identify and analyze diverse cancer types, reducing the need for large, stain-specific datasets.[1076]
- Researchers from Memorial Sloan Kettering Cancer Center and the Tisch Cancer Institute at Mount Sinai (both in New York, USA) have developed an AI-based model called SCORPIO. This uses routine blood tests to predict whether individual cancer patients will benefit from immune checkpoint inhibitors. These are immunotherapy drugs that release the brakes on immune cells, increasing their ability to attack cancer. But the drugs are expensive, can cause severe side effects, and are ineffective for most patients. SCORPIO helps to select patients most likely to benefit from the drugs.[1077]
- PFA, Denmark's largest pension fund, is using an AI model, developed by experts including quantum physicists and data scientists and using only standard data provided by members and 29 data points, to identify scheme members at risk of

[1072] https://www.labmedica.com/medica-2023/articles/294799318/noul-showcases-ai-driven-blood-and-cancer-diagnostic-platform.html
[1073] https://www.labmedica.com/pathology/articles/294798826/new-ai-algorithm-for-use-on-eight-types-of-cancer-trained-on-seven-scanner-models.html
[1074] Generative AI is capable of scanning test results, diagnosing illnesses, and suggesting treatments. It is also able to detect inefficiencies, advance drug discovery (including the generation new molecules), and improve clinical-trial planning and execution.
[1075] https://www.labmedica.com/pathology/articles/294798666/worlds-largest-image-based-ai-models-for-digital-pathology-and-oncology-to-fight-cancer.html
[1076] https://www.labmedica.com/pathology/articles/294803454/ai-model-excels-at-analyzing-diverse-cancer-types-and-unseen-ihc-data.html
[1077] https://www.labmedica.com/immunology/articles/294803642/index.php

long-term illness and the measures it has taken – calling in members, discussing their chronic conditions and advising on early and proactive action – has led to a 70% lowering of that risk.[1078]

- In February 2024, two new AI models designed to accelerate scientific discovery were introduced. One is Google's 'Co-scientist' which was designed to assist scientists by mirroring 'the reasoning process underpinning the scientific method' in order to generate likely and novel hypotheses. A team from Imperial College London gave the model a prompt about an antibiotic resistance problem they had been working on for 10 year. Within 48 hours, the model had not only reproduced their key hypothesis, it also also provided four plausible alternatives, including one which was completely original. Another model is 'Evo 2' which has been built by the Arc Institute to read, interpret, and design entire genomes. In tests, the model accurately predicted whether certain genetic mutations would cause cancer, which would take human researchers months to do.[1079]
- The use of generative AI to uncover the genetic networks driving complex human diseases using a computational tool, known as Transcriptome-Wide Conditional Variational Auto-Encoder (TWAVE). The tool represents a breakthrough in linking genotype to phenotype by shifting the analytical focus from individual genes to coordinated gene groups. Through a combined machine learning and optimization framework, TWAVE pinpoints the gene changes most likely to transition a cell from healthy to diseased or vice versa.[1080]
- A study by NHS England has found that using AI software to interpret brain scans could triple stroke recovery rates by diagnosing patients faster and helping doctors make faster decisions about the right course of treatment'.[1081]
- The application by scientists at Flinders University of AI techniques to improve both the quality of DNA profiling and the efficiency of polymerase chain reaction (PCR) cycling conditions. The scientists have built a system that enables a 'smart PCR' process to provide real-time feedback, allowing a machine-learning (ML) algorithm to make instantaneous adjustments to PCR conditions.[1082]
- ML can radically reduce the workload of cell counting for disease diagnosis.[1083] Researchers at Benihang University (Beijing, China) have developed the new scheme for training a convolutional neural network (CNN) – a type of ML that mirrors the connection structure of the human visual cortex. The number and type

[1078] https://www.ipe.com/news/pfa-says-ai-model-has-led-to-70-drop-in-long-term-illness-risk/10070534.article
[1079] *Human Progress Newsletter*, 23 February 2025
[1080] https://www.labmedica.com/molecular-diagnostics/articles/294805317/ai-tool-identifies-gene-combinations-causing-complex-illnesses.html
[1081] https://humanprogress.org/ai-brain-scans-can-triple-stroke-recovery-rates-nhs-analysis-finds
[1082] https://www.labmedica.com/molecular-diagnostics/articles/294802853/ai-powered-smart-pcr-system-to-revolutionize-clinical-diagnostics.html
[1083] In a blogpost in July 2024, Rose Nguyen and Diana Philip point out that: 'The human body has about three billion DNA base pairs, 20,000 encoded proteins, and approximately 37 trillion cells. Understanding that level of complexity requires machine learning, as does exploring how the billions of possible chemical compounds in the universe interact with the body to find valuable drugs to treat its diseases'; https://www.bailliegifford.com/en/uk/institutional-investor/insights/ic-article/2024-q2-ai-in-healthcare-10048272/

of cells in the blood often play a crucial role in disease diagnosis, but the cell analysis techniques currently used to perform such counting of blood cells – involving the detection and measurement of physical and chemical characteristics of cells suspended in fluid – are expensive and require complex preparations. Worse still, the accuracy of cell analyzer machines is only about 90%.[1084]

- The use of ML to grow artificial organs, especially to tackle blindness. Researchers from the Moscow Institute of Physics and Technology, Ivannikov Institute for System Programming, and the Harvard Medical School-affiliated Schepens Eye Research Institute have developed a neural network capable of recognizing retinal tissues. Unlike humans, the algorithm achieves this without the need to modify cells, making the method suitable for growing retinal tissue for developing cell replacement therapies to treat blindness and conducting research into new drugs. The method could be adapted to create other human artificial organs.[1085]
- The use of ML, matrix factorization, deep learning, and topological data analysis, to improve understanding of the complex relationships between diseases or multimorbidities.[1086]
- Combining ML, epigenetics, and next-generation sequencing (NGS) in a blood test for multi-cancer early detection[1087]
- Combining AI and ML, e.g., in a blood test to identify cancer before it is visible or symptomatic.[1088]
- Researchers at the US National Cancer Institute have created an AI tool that uses a patient's blood to predict if the patient's cancer will respond to immune checkpoint inhibitors. The ML model, named Logistic Regression-Based Immunotherapy-Response Score (LORIS), assists doctors in determining the efficacy of immunotherapy drugs for the patient's cancer treatment.[1089]
- The use of digital technologies, such as predictive analytics, by life companies for product innovation.[1090] Predictive analytics makes use of data mining, predictive modelling and ML to analyze current and historical data in order to make predictions about the future. An example is a joint venture between Longevitytech.fund and Vesttoo to harness the power of AI and ML to forecast and price long-tail risks such as longevity, excess mortality, lapse, as well as Value-in-Force (VIF) monetization and excess mortality Industry Loss Warranties (ILW) and transfer them to the capital markets.[1091]

---

[1084] https://www.labmedica.com/hematology/articles/294793039/machine-learning-radically-reduces-workload-of-cell-counting-for-disease-diagnosis.html
[1085] Machine learning will help to grow artificial organs, Open Access Government, 7 July 2020; https://www.openaccessgovernment.org/grow-artificial-organs/89945/
[1086] Abdelaali Hassaine, Gholamreza Salimi-Khorshidi, Dexter Canoy, and Kazem Rahimi (2020) Untangling the complexity of multimorbidity with machine learning, *Mechanisms of Ageing and Development*, Volume 190, September 2020, 111325; https://doi.org/10.1016/j.mad.2020.111325
[1087] https://www.labmedica.com/molecular-diagnostics/articles/294793279/index.php
[1088] https://www.labmedica.com/hematology/articles/294791085/blood-test-combines-ai-and-machine-learning-to-detect-cancer-before-it-becomes-visible-or-symptomatic.html
[1089] https://www.labmedica.com/immunology/articles/294801415/index.php
[1090] Demand for predictive analytics rises among life insurers, *The Actuary*, 26 November 2020.
[1091] PRNewswire, 7 January 2021.

- IntelliGenes software developed by Rutgers Health combines conventional statistical methods with ML algorithms to generate personalized patient predictions and provide a visual representation of the biomarkers significant to disease prediction.[1092]
- The development of a blood test, called ClarityDX Prostate, to improve the detection of prostate cancer – which affects one-in-six men – and reduces invasive biopsies. The test uses the ClarityDX ML algorithm which takes account of multiple factors, including PSA (prostate-specific antigen) levels to provide a more accurate risk score for aggressive prostate cancer. The test results can then be used to decide if a biopsy is needed.[1093]
- The use of an AI-based method to improve the diagnosis of drug-resistant infectious diseases, particularly those caused by deadly bacteria like tuberculosis and staphylococcus. The method more accurately detects genetic markers of antibiotic resistance in *Mycobacterium tuberculosis* and *Staphylococcus aureus*, which could facilitate faster and more effective treatment. Scientists at Tulane University (in New Orleans) have developed a Group Association Model (GAM) which builds on machine learning to identify genetic mutations associated with drug resistance; it operates without relying on prior knowledge of resistance mechanisms, making it more adaptable and capable of identifying previously undetected genetic alterations.[1094] In November 2025, it was announced that SpaL, a drug combination based on the new antibiotic sorfequiline, reduced the treatment time for curing tuberculosis, the world's deadliest infectious disease, to two months.[1095]
- The application of 'wellbeing technology' to improve the quality of people's lives across four dimensions:
    - Maintaining and improving mental health, via stress-relief technology utilizing biometric data, e.g., heart and respiration rate; and applications and services to alleviate stress and anxiety
    - Maintaining and improving physical health, via fitness tracking on mobile apps and wearable devices; rehabilitation using virtual reality and augmented reality; and telehealth that provides online healthcare services
    - Enhancing social wellbeing, via social networks that prevent loneliness and isolation; and technology that reinvigorates local communities
    - Supporting people to be financially secure, via apps for managing spending and savings goals, and robo-advisors utilizing AI to select investment strategies.[1096]

[1092] https://www.labmedica.com/molecular-diagnostics/articles/294799996/first-of-its-kind-software-uses-ai-and-ml-for-personalized-disease-prediction.html
[1093] https://www.labmedica.com/molecular-diagnostics/articles/294798810/innovative-blood-test-to-revolutionize-prostate-cancer-detection-and-reduce-invasive-biopsies.html
[1094] https://www.labmedica.com/microbiology/articles/294804598/new-ai-based-method-improves-diagnosis-of-drug-resistant-infections.html
[1095] https://www.telegraph.co.uk/global-health/science-and-disease/new-tb-treatment-for-worlds-deadliest-infectious-disease/
[1096] https://www.pensionpolicyinternational.com/the-future-of-a-hyper-aging-society-navigated-by-well-being-technology/

- Scientists at ETH Zurich and the University of Zurich have combined biomedical technology and mechanical engineering to create a robotic system to give more accurate cancer diagnoses by analyzing tissue samples in their entirety, an improvement over the traditional approach of slicing tissue samples, examining them for abnormalities under a microscope, and then staining suspect cells. The new approach automates these processes and finally analyzes the tissue using 3D imaging software and training algorithms.[1097]
- Robotic-assisted surgery can reduce the human risk and lead to faster recovery times for patients.[1098]
- Quantum computing is still in the early stage of development, but is likely to revolutionize a number of industries. Whereas classical computers use binary bits of 0s and 1s stored on silicon chips, quantum computers use quantum bits or qubits and subatomic particles like electrons and photons. A qubit can represent 0, 1, or a superposition state of both 0 and 1 simultaneously, where the probability of observing a 0 or 1 depends on the wave functions of the qubit. The advantage of qubits is vastly increased storage capacity compared with bits. To illustrate, 2-bits can store at any one time only one of 00, 01, 10 and 11, while 2-qubits can simultaneously store both 00, 01, 10 and 11 and 00, 01, 10 and 11. Similarly n-bits can only store one value at a time between 0 and $2^n$ total possible values, while n-qubits can simultaneously store any value at a time between 0 and $2^n$ total possible values and *every* value 0 and $2^n$ total possible values. IBM's quantum computer, Eagle, has 127-qubits. To match the storage capacity of this computer, a classical computer would have to have more bits than there are atoms in the human race. IBM's Summit, the world's fastest supercomputer, is around 158 million times slower than Google's quantum computer. In December 2024, in another step towards generating reliable, scalable quantum computers, Google announced that a new chip, named Willow, had significantly improved how long qubits can maintain their quantum states (qubits easily lose their quantum properties when interacting with their environment) and also reduced computational errors while increasing the number of qubits (even under controlled conditions, quantum operations are prone to errors).[1099]

  Quantum computers also use the entanglement property whereby two subatomic particles interact so the state of one impacts the state of the other. This is needed to overcome the 'Schrödinger Cat' paradox of quantum superposition whereby a cat in a sealed box is simultaneously alive and dead until the box is opened and the true state of the cat is observed. By analogy, once an attempt is made to read a qubit, the superposition of multiple states collapses and its computing power is lost. Quantum entanglement is used to observe the qubit indirectly by reading its entangled partner and inferring the state of the original qubit without it collapsing from superposition. Quantum computer are designed to process large complex

[1097] https://www.labmedica.com/pathology/articles/294799080/index.php
[1098] PI Magazine: ESG Club, April 2024.
[1099] https://blog.google/technology/research/google-willow-quantum-chip

data sets. They can used in biochemistry to create models of proteins and in medicine to create new drugs without having to go through long trial periods.[1100]

A related development is AgeTech which has been described as the application of technologies, such as e-health, robotics, artificial intelligence and mobile devices to support the health and independence of older people.[1101] Recent examples include:

- Combining AI and robotics to improve healthcare for the elderly. For example, Taiwan has created an AI robot which can interact with and accompany elderly when they are outside the hospital. This robot analyzes the elderly's medical records, reminds them to take their medication, and measures their blood sugar levels. The robot also helps doctors give more timely diagnosis and monitor patients. It is able to combine the physiological data of patients and upload it to the cloud, where doctors can view it remotely. This allows them to detect any abnormalities and immediately give a diagnosis. AI also helps doctors better communicate with their elderly patients. Most of the elderly in Taiwan speak only Hokkien. But an AI program has been developed that automatically translates Mandarin to Hokkien, and vice versa, to assist doctor-patient communication.[1102] China has developed similar robots to provide personalized support, companionship and ensure the safety of the elderly.[1103]
- South Korea also has an aging problem, and, as a consequence of having the world's lowest birth rate at 0.7 children per woman, it will become a super-aging society – where more than 20% of the total population is above 65 and older – in 2025. In 2020, in response to the acute shortage of healthcare workers during the pandemic, the internet provider Naver Corporation created the CareCall system, an AI call robot designed to assist public health centres check and report Covid-19 symptoms. This has now developed into CareCall partnerships with local authorities, whereby the robot will call people weekly at the same time to help manage disease and medication, advise on diet and exercise, detect emotional problems, and help prevent lonely deaths. The calls are personalized, last only a few minutes, and the robot is trained to sound as natural as possible and recall details from previous discussions to increase the level of emotional care. At the end of the call, a report is sent to the local authority, with any points of concern

[1100] Congressional Research Service (2023) *Quantum Computing*, Report R47685, 7 September, https://crsreports.congress.gov/product/pdf/R/R47685; Martin Giles (2019) Explainer: What is a quantum computer?, MIT Technology Review, 29 January, https://www.technologyreview.com/2019/01/29/66141/what-is-quantum-computing; Vidar (2021) Google's Quantum Computer Is About 158 Million Times Faster Than the World's Fastest Supercomputer, 28 February, https://medium.com/predict/googles-quantum-computer-is-about-158-million-times-faster-than-the-world-s-fastest-supercomputer-36df56747f7f

[1101] Alan Gow (2024) How to approach the use of AgeTech, 26 November, Global Research Institute in Health and Care Technologies, Heriot-Watt University; https://www.hw.ac.uk/uk/research/long-read/how-to-approach-the-use-of-agetech.htm

[1102] https://govinsider.asia/health/how-ai-and-robots-are-caring-for-the-elderly-in-taiwans-ageing-society-dr-jenny-su-ncku/

[1103] https://www.pensionpolicyinternational.com/robot-caregivers-chinas-solution-for-aging-population/

> followed up by human healthcare professionals. Users report an overall 90% satisfaction rate: some feel comforted by the calls, while others have made lifestyle changes following discussions about eating and exercising. The national government is planning to use AI to monitor high-risk groups by analyzing power and water usage patterns to identify any signs of unusual behaviour.[1104]

Clearly these developments are going to have a significant effect on diagnosing illnesses and improving health care and, in turn, on projections of future life expectancy.

Despite this, ethical concerns have been raised. For example, a study by Padhan et al. (2023) in the *Cureus Journal of Medical Science on AI and Robotics* recognised the potential benefits of AI algorithms in monitoring the health of the elderly, but argued that there should be robust security measures and clear consent procedures in place to address privacy concerns over the collection and use of personal health data: 'Cloud technologies that allow for real-time data analytics from numerous sources across integrated organizations and data sharing need to be carefully evaluated, information security needs to be maintained, and the threat of cyberattacks needs to be minimised. …In addition, the issue of autonomy arises when older adults rely heavily on AI and robotic systems, raising questions about decision-making and the potential loss of human connection. …The employment of robots by older persons may increase the danger of dishonesty, infantilization, and confusion among them as to why their human caretakers are using technology rather than face-to-face consultations'. The study called for guidelines and regulations to ensure responsible use of the technology.[1105]

Further, robotic systems and AI are likely to have a significant impact on labour employment. Daron Acemoglu and Pascual Restrepo (2020), for example, estimated that, between 1990 and 2007, each additional robot added in manufacturing in the US replaced about 3.3 workers nationally and lowered wages by around 0.4%. On the other hand, robots can help economies with an aging population and a declining workforce, as Acemoglu points out: 'With an ageing population, there may be an impetus for employers to invest more in machinery, especially those that would substitute for certain types of labour. That may increase productivity. If you look at the three fastest-ageing economies of the 90s, 2000s and 2010s – South Korea, Japan and Germany – they responded to ageing by investing a lot in robotics and associated technologies'.[1106] Generative AI is now leading to lay-offs (which could be as high as 30%) in the very tech companies that invented it, such as Microsoft, Meta, eBay, SAP and PayPal. Machines are now much better at

[1104] https://www.telegraph.co.uk/global-health/climate-and-people/south-korea-elderly-care-robots-artificial-intelligence

[1105] Srikanta Padhan, Avilash Mohapatra, Senthil Kumar Ramasamy, and Sanjana Agrawal (2023) Artificial Intelligence (AI) and Robotics in Elderly Healthcare: Enabling Independence and Quality of Life, *Cureus* 15(8): e42905; doi:10.7759/cureus.42905. Similar concerns have been raised in a presentation entitled 'The double-edged sword conundrum', by Professor Andrew Sixsmith, Director of the Science and Technology for Aging Research (STAR) Institute at Simon Fraser University in Canada and Co-founder of AGE-WELL, Canada's AgeTech network; https://www.hw.ac.uk/uk/research/long-read/how-to-approach-the-use-of-agetech.htm

[1106] https://www.telegraph.co.uk/business/2025/10/25/robots-save-britains-economy-ageing-population/

programming than humans. Some studies predict that 40% of all jobs are at risk from AI. Many of the remaining jobs will be enhanced by AI, however.[1107]

Finally, there have also been growing concerns by industry insiders about the risks of AI becoming smarter than humans. For example, Eliezer Yudkowsky, head of research at the Machine Intelligence Research Institute, gives this stark warning: 'Many researchers steeped in these issues, including myself, expect that the most likely result of building a superhumanly smart AI, under anything remotely like the current circumstances, is that literally everyone on Earth will die. … To visualize a hostile superhuman AI, don't imagine a lifeless book-smart thinker dwelling inside the internet and sending ill-intentioned emails. Visualize an entire alien civilization, thinking at millions of times human speeds, initially confined to computers – in a world of creatures that are, from its perspective, very stupid and very slow. A sufficiently intelligent AI won't stay confined to computers for long. In today's world you can email DNA strings to laboratories that will produce proteins on demand, allowing an AI initially confined to the internet to build artificial life forms or bootstrap straight to postbiological molecular manufacturing'. While some, including Elon Musk, have called for 'all AI labs to immediately pause for at least 6 months the training of AI systems more powerful than GPT-4' since AI presents 'profound risks to society and humanity',[1108] Yudkowsky argues that pausing is not enough and instead we must 'Shut it all down'.[1109]

In February 2026, CEPI, the Coalition for Epidemic Preparedness Innovations, informed the Munich Security Conference that 'Rapid progress in AI – including genome language models already used to design novel bacteriophages – raises the prospect of misuse, enabling the modification or creation of synthetic pathogens that could challenge existing vaccine and medical countermeasure development paradigms. The pace of AI innovation therefore heightens the need for sustained investment, governance and readiness to address AI-enabled biological threats'.[1110]

***Implications of global aging for financial markets and economic growth***

Aging populations – as a consequence of both declining fertility and mortality – could have a big influence on the future returns and the volatility of returns on the assets in which pension funds and PRT providers invest, in addition to their impact on government spending on pensions and the sustainability of pension systems, as well as on the rate of economic growth.

Long-term real interest rates in developed countries have been falling since the mid-1980s. Before that they averaged around 3% back to the 1950s. They reached 0% in around 2012

[1107] Jeremy Warner (2024) The AI jobs slaughter is coming for tech first, *Daily Telegraph*, 13 February.
[1108] Billy Perrigo (2023) Elon Musk Signs Open Letter Urging AI Labs to Pump the Brakes, *Time,* 29 March; https://time.com/6266679/musk-ai-open-letter/
[1109] Eliezer Yudkowsky (2023) Pausing AI Developments Isn't Enough. We Need to Shut it All Down, *Time*, 29 March; https://time.com/6266923/ai-eliezer-yudkowsky-open-letter-not-enough/
[1110] https://www.telegraph.co.uk/global-health/science-and-disease/ai-could-trigger-new-pandemic-intelligence-chiefs-warned/

and fell to as low as -2% in some European countries. The European Systemic Risk Board (2021) explains this new low interest rate environment (LIRE) in terms of:

- demographic developments including rising life expectancy and falling population growth rates (Acemoglu and Johnson (2007), Backus et al. (2014), Aksoy et al. (2019), Ferrero et al. (2019));
- a falling (relative) price of investment goods and a rising share of intangible investment (Karabarbounis and Neiman (2014), Thwaites (2015));
- slowing pace of technological innovation (Gordon (2016));
- falling marginal product of capital (related to demography and technical progress) (Cochrane (2021));
- rising wealth and income inequality (Summers (2014), Rachel and Summers (2019))
- rising savings rates in developing countries and the consequent increasing demand for assets issued by advanced economies (Bernanke (2005)); and
- declines in the consumption/wealth ratio which predict depressed real rates for an extended period of time (Gourinchas and Rey (2019)).

Summers (2013) describes the LIRE as 'secular stagnation' and some expect it to last for an extended period of time, a view supported by, e.g., Blanchard et al. (2014), Gourinchas and Rey (2019), Kiley (2020), Auclert et al. (2021), and Obstfeld (2025). For example, Auclert et al. (2021), using an overlapping generations model, together with population forecasts and household surveys for 25 countries, predict that aging will increase global wealth/GDP ratios, lower global asset returns and widen global financial imbalances over coming decades. The lower returns are explained by the fact that, due to aging, investment declines relative to savings, while differences in demographics across countries will result in advanced countries, such as the US and Germany, experiencing declining net foreign assets, whereas China and India's net foreign assets will increase significantly up to 2100. Vlieghe (2022) argues that the stock of wealth held by the population has a bigger effect on interest rates than savings flows, especially if there is a big increase in the value of a key asset such as housing. Accordingly, a high (actual and desired) stock of assets can dominate any decline in the savings of older people – which again contributes to lower returns. Obstfeld (2025) also argues that long-term real interest rates will remain low in the future. The key demographic impact is from increasing but uncertain life expectancy which leads retirees to actually save more than the life-cycle model predicts as a result of precautionary and bequest motives.[1111] Other factors reducing real rates include subdued economic growth (and hence GDP) driven by lower labour force growth due to aging as well as geopolitical fragmentation and uncertainty depressing investment and further raising precautionary saving.

The European Systemic Risk Board (2021) identifies four key areas of concern in the LIRE:

[1111] The standard life-cycle model of Ando and Modigliani (1963) predicts that individuals will save when they are middle aged and dissave when they are young and old; they will also run down their wealth to zero during retirement. However, the standard model assumes a fixed lifetime and no bequest motive. Uncertain lifetimes and positive bequest motives will result in higher end-of-life savings and wealth than predicted by the standard model.

- the profitability and resilience of banks: as net interest margins have trended downwards, banks have responded by increasing interest-earning assets and shifting the composition of their assets towards riskier market segments – including towards commercial real estate, consumer lending and small and medium-sized enterprises (SMEs);
- the indebtedness and viability of borrowers, as the LIRE facilitates higher leverage and encourages search-for-yield behaviour;
- systemic liquidity risk, as the LIRE have made the financial system more sensitive to market shocks;
- the sustainability of the business models of insurers and pension funds offering longer-term return guarantees, as they experience increasing pressures in the LIRE.[1112]

Focusing on the demographic developments, Jen (2007)[1113] argued that there are four important economic and financial implications:

- The level of real long-term interest rates will be affected by the changing fiscal outlook of countries. Potential economic growth rates vary with these demographic trends. Potential economic growth in countries with high dependency ratios will likely slow.[1114] Not only will the growth of labour supply slow, but justifications for capital accumulation will be less compelling in an aging country. Further, as the population of a country ages, ceteris paribus, the aggregate wage bill may shrink, reducing tax receipts. At the same time, medical expenditures and other healthcare-related spending may crowd out the education expenses needed to enhance the productivity of the shrinking work force.[1115] The end result is a shrinking tax base and rising budgetary demands. Without changes in the retirement age or female participation in the labour force, what this means is that the levels of real interest rates in countries with aging populations may rise above what could be justified by their potential growth rates, as public borrowing needs grow and the private sector starts to dis-save during retirement, both of which drive up interest rates.

[1112] See also John Fell, Tuomas Peltonen and Richard Portes (2021) Lower for longer – macroprudential policy issues arising from the low interest rate environment, 2 June; https://voxeu.org/article/macroprudential-policy-issues-arising-low-interest-rate-environment

[1113] Drawn from Jen (2007) – with updated data. See also Bohl et al. (2016).

[1114] One study estimated that in Europe, a 1% increase in the old age dependency ratio (of those aged 65+ to those in work) decreased real per capita GDP by 0.4% (A 'back of the envelope' evidence on aging and growth in Europe, www.reforming.it, 30 March 2018). Key European countries are attracting headlines like this: 'Aging Germany Is Running Out of Workers, Putting Europe's Largest Economy at Risk'; https://www.pensionpolicyinternational.com/aging-germany-is-running-out-of-workers-putting-europes-largest-economy-at-risk/. In 2022, the German government announced that it wanted to attract 400,000 qualified workers from abroad each year to tackle both the demographic imbalance and labour shortages in key sectors that risk undermining the recovery from the coronavirus pandemic; https://www.pensionpolicyinternational.com/germany-wants-to-attract-400000-skilled-workers-from-abroad-each-year/

[1115] In theory, investment to enhance total factor productivity could keep output growth high, even with a shrinking population.

Aksoy et al. (2019) provide empirical evidence from OECD countries which confirm that population aging leads to subdued output growth,[1116] higher net savings and lower interest rates. In particular, an increase in the share of the dependent population and a decline in the share of the working age population lead to a statistically significant decline in real interest rates. However, these rates would be even lower without the impact of increased public borrowing and retiree dissaving. Auclert et al. (2021) also argue that increasing government debt may counteract the lowering effect of aging on asset returns, while enhancing the effect on the wealth/GDP ratio as investors add the newly issued government bonds to their existing asset holdings.

- Yield curves should flatten in countries with aging populations and steepen in countries with younger populations. The shapes of the yield curves may change as well. With the monetary policy of most central banks driven by formal or informal inflation targeting, demographic trends could distort the shapes of the yield curves.

  In a country with an aging population (such as the US), in the short term, the Fed would need to have higher policy rates to stabilize inflation as potential growth decelerates. In other words, it should be more sensitive to lingering inflationary pressures at every given level of growth rate of aggregate demand. However, the long-term interest rate should be commensurate with the new, lower, potential growth rate and therefore should be lower, notwithstanding the possibility of a rise in the borrowing cost and retiree dissaving. This implies a flatter yield curve in the US and similar countries with aging populations.

  Similar logic suggests that the accelerating potential growth rates in younger countries would tend to steepen their yield curves.

- Aging may affect the preferred structure of financial portfolios. Different generations have different risk preferences. There are two competing theories. On the one hand, it is thought that global aging may raise the equity premium, as aging households become less willing to warehouse risk. As a result, aging could benefit bond markets relative to equity markets. Most academics would agree with this.[1117]

[1116] Farouki Majeed, chief investment officer of the $19bn School Employees Retirement System of Ohio Fund, put it this way: 'forecasts of GDP growth …have an implied demographic element. It's incorporated in GDP in the sense that if you look at GDP as a two-factor model, it's population times productivity growth', implying that population aging slows down both working population and productivity growth, and hence GDP growth (quoted in Simon Hoyle (2024) The long and the short of harnessing demographics for better returns, 4 September; https://www.top1000funds.com/2024/09/the-long-and-the-short-of-it-harnessing-demographics-for-better-returns/

[1117] So would some practitioners. For example, Pictet Asset Management (Picket AM)'s chief strategist Luca Paolini has said: 'An aging society tends to be…more conservative. More conservative means less risky. [The elderly] tend to stick with the status quo, normally' (quoted in Simon Hoyle (2024) The long and the short of harnessing demographics for better returns, 4 September; https://www.top1000funds.com/2024/09/the-long-and-the-short-of-it-harnessing-demographics-for-better-returns/

However, recent experience in Japan suggests an interesting alternative hypothesis. A fixed retirement age, coupled with ever improving life expectancy, has created a 'longevity risk', whereby retirees can no longer be confident of their ability to defend their lifestyle if they end up living much longer than they expect at the time of their retirement. In the case of Japan, this has led to more risk-taking, not less, as retirees try to enhance their expected investment returns by diversifying away from assets with low credit risk. In contrast to the first hypothesis, this alternative hypothesis suggests that retirees should have a bigger appetite for equities.[1118]

- Asynchronous aging patterns in different parts of the world have implications for current account (C/A) imbalances. C/A imbalances are essentially savings-investment gaps.[1119] If demographic trends drive the savings patterns in countries, then C/A imbalances should also be affected. The permanent income (or life cycle) hypothesis suggests that very 'young' and very 'old' countries tend to dis-save, while those with low dependency ratios should be saving. However, the constellations of the C/A imbalances in the world are not consistent with this pattern.

Jen (2007) continues: 'What this may imply is that, as Japan ages, its savings rate should decline, as retirees start to draw down their savings. This may very well start to happen. With a high C/A surplus position [3.6% of GDP in 2023[1120]], this prospective trend should not pose a problem for Japan. However, the same argument applies to the US, but with a high C/A deficit [3.3% of GDP in 2023[1121]], the US does not seem to have a great deal of scope to dis-save further. [Two other countries with large C/A surpluses (Germany and China)] are themselves facing aging pressures, and therefore downward pressures on savings. The implications for the dollar will be a function of how fast the US savings rate changes relative to that of the rest of the world'.

More recently, Goodhart and Pradhan (2020) argue that 'the underlying forces of demography and globalization will shortly reverse three multi-decade global trends – it will raise inflation and interest rates. …Deflationary headwinds over the last three decades have been primarily due to an enormous surge in the world's available labour supply, owing to very favourable demographic trends and the entry of China and Eastern Europe into the world's trading system. …These demographic trends are on the point of reversing sharply, coinciding with a retreat from globalization. The result? Aging can be expected to

[1118] Picket AM's Luca Paolini also has some sympathy for this argument: 'On equity versus bonds, the theory until recently was if you live longer, obviously you are more risk-averse, so in theory you prefer bonds to equities. Then we see this big rise in inflation, [and] we say wait a second. If you are old and you have a pension, what is the best action, bonds or equities? Probably equities' (quoted in Simon Hoyle (2024) The long and the short of harnessing demographics for better returns, 4 September; https://www.top1000funds.com/2024/09/the-long-and-the-short-of-it-harnessing-demographics-for-better-returns/

[1119] This follows from the national income accounting identity: savings – investment = exports – imports (if government expenditure = taxation). If savings are low relative to investment, this will be associated with a current account deficit.

[1120] https://www.statista.com/statistics/1171474/japan-current-account-balance-as-share-of-gdp/; https://www.theglobaleconomy.com/Japan/current_account/

[1121] https://data.worldbank.org/indicator/BN.CAB.XOKA.GD.ZS?locations=US

raise inflation and interest rates, bringing a slew of problems for an over-indebted world economy, but is also anticipated to increase the share of labour [in national income], so that inequality falls'. They point out that higher public debt (associated with increased health, pension and military expenditures) could also push interest rates higher. McNicholl (2021), in his review of Goodhart and Pradhan's book, commented that the authors appear to have ignored further effective labour supply coming from India and Africa, while Obstfeld (2024) argues that the effects of the boost to global labour supply from China had worked themselves out by 2010.

There are differing views on whether population aging leads to price volatility in asset markets, which would be the case if, for example, a relatively large old generation attempted to sell its asset holding to a relatively smaller younger generation to finance its retirement. Mankiw and Weil (1989) argue that it does – at least in the housing market. However, Poterba (2001) could find no strong cohort effect. He estimated a flat financial asset profile in old age, indicating that there was little evidence of a mass disposal of assets in old age – at least in the US – and conjectured that this might be for precautionary or bequest motives, as suggested earlier. Similarly, Börsch-Supan (2006), using an open-economy model, predicts that capital outflows will restrict asset price reductions in the domestic economy, suggesting that open economies can avoid some of the demographic effects that depress saving rates and the rate of return on capital. On the other hand, it is possible that imperfections in international capital and traded goods markets could well contribute to international asset price volatility arising from differential aging across countries.[1122]

The bottom line, according to Jen (2007) is that 'demographic trends have important economic and financial implications'.

This is confirmed by a 2024 study from the McKinsey Global Institute called *Dependency and Depopulation* which calculated that as birth rates decline, some of the world's most advanced economies would need to at least double their productivity growth rates to sustain

[1122] This is an implication of Borio and Disyatat's (2015), Ford and Horioka's (2016, 2017), and Horioka and Ford's (2017) explanation of two of the so-called macroeconomic puzzles identified by Obstfeld and Rogoff (2000), in particular, the Feldstein-Horioka puzzle and the purchasing power and exchange rate disconnect puzzle. The former puzzle, identified by Feldstein and Horioka (1980), is the high correlation between domestic savings and investment rates when there should be no correlation if capital mobility is perfect. The second puzzle, identified by Meese and Rogoff (1983), is that real exchange rates can deviate from purchasing power parity exchange rates for considerable periods which should not be possible if there was a high degree of mobility in internationally traded goods. However, Borio and Disyatat (2015), Ford and Horioka (2016, 2017) and Horioka and Ford (2017) argue that these are not real puzzles at all. Borio and Disyatat (2015) argue that the puzzles are a consequence of the 'failure to maintain a clear distinction between net resource flows [i.e, the gap between savings and investment] and financing flows'. Ford and Horioka (2016) make the same point in a different way: 'financial markets alone cannot achieve net transfers of financial capital and cannot equalize real interest rates across countries – [and this] also helps explain why previous attempts to connect changes in the exchange rate to economic fundamentals have not been successful'. It is clear that, given the slow response of the global economic and financial system to savings, investment and trade imbalances, then differential population aging will add an additional source of asset price volatility.

historical improvements in living standards.[1123] In the case of China, GDP per capita growth could slow by 0.4% annually on average from 2023 to 2050, unless productivity growth increases by two to four times or people work one to five hours more per week.

The study also predicted that 'consumers and workers will be older and increasingly in the developing world. Seniors will account for one-quarter of global consumption by 2050, double their share in 1997. Developing countries will provide a growing share of global labor supply and of consumption, making their productivity and prosperity vital for global growth. …In confronting the consequences of demographic change, societies enter uncharted waters. Absent action, younger people will inherit lower economic growth and shoulder the cost of more retirees, while the traditional flow of wealth between generations erodes. Long-standing work practices and the social contract must change. More fundamentally, countries will need to raise fertility rates to avert depopulation – a societal shift without precedent in modern history'.

What pension funds need is, as Ferrero et al. (2019, p275) point out: 'structural reforms and fiscal policies that encourage later retirement and promote innovation and investment in research and development. These policies would also reduce the negative impact of aging on potential output growth, although their effects would materialize only gradually. An acceleration in technological innovation (Brynjolfsson and McAfee, 2014), arising from the unfolding of the "the second machine age"[1124] could offset the impact of adverse demographic developments and raise potential output growth'.

Indeed, Acemoglu and Restrepo (2022) have found evidence that aging, because it creates a shortage of middle-aged workers specializing in manual production tasks, leads to greater industrial automation. Aging is associated with the greater adoption of robots and other automation technologies and that more automation innovation occurs in countries undergoing faster aging. Further, productivity improves relatively in industries that are more amenable to automation.

However, there are mixed views on the impact of artificial intelligence on productivity and growth. On the one hand, Professor Oded Galor of Brown University argues that a significant component of the sustained growth in income per capita over the past 150 years can be explained by falling birth rates, rising education and technological progress which have led to increases in human capital and long-term prosperity: 'The fact that we have scarcity of labour will expedite the adoption of AI, and . . . given the incredible potential, will see incredible growth'. On the other hand, UK demographer Paul Morland believes it is 'very optimistic' to think that AI could compensate for the negative effects of demographic change: 'If we were about to get a revolution in productivity through AI, we'd already be seeing it. Despite the technological advances of recent decades, productivity of the more advanced countries in the world has been growing at a slower and

[1123] McKinsey Global Institute (2024) *Dependency and Depopulation*; https://www.mckinsey.com/mgi/our-research/dependency-and-depopulation-confronting-the-consequences-of-a-new-demographic-reality

[1124] 'The automation of a lot of cognitive tasks that make humans and software-driven machines substitutes, rather than complements'.

slower rate'. Christophe André, an economist at the OECD, adds: 'Technological progress can help, but is unlikely to be sufficient to avoid a slowdown in GDP per capita growth rates, unless the most optimistic hopes about AI materialise'. Further, the European Bank for Reconstruction and Development estimates that AI could provide, on average, about half of the productivity growth required to compensate for the effects of demographics in selected EU countries under a high-impact scenario.[1125]

At the same time, a report by the American Association of Retired Persons found that the 50-year-plus population accounts for a large portion of global GDP and recommends that policies should be implemented that enable older citizens to be as productive as possible. This would require governments and companies to abandon ageist stereotypes and make the kind of investments that harness the opportunities unleashed by increased longevity, such as policies to promote lifetime training and initiatives to boost late-life entrepreneurship. The report looked at the 50-plus population across 79 countries between 2020 and 2050, and predicts that their contribution to global GDP could increase between 2020 and 2050 from $45 trillion to $118 trillion. Much of that would be driven by people working longer and continuing to contribute in their 50s, their 60s, and even their 70s, depending on their health.[1126]

Workers are also taking a more flexible attitude to retirement in some countries. For example, a survey by abrdn for its *Class of 2022* study of 2,000 UK workers due to retire in 2022 found that 66% planned to remain employed in some form compared to 56% in 2021 and 34% in 2020. The survey found that 24% will go part-time with either the same job or a new one, 15% will continue to work for their own business, and 12% plan to become entrepreneurs and start their own business. The main reasons cited for 'flexi-retirement' include needing the income (31%) and wanting to keep busy (32%).[1127]

### *Climate change and sustainable development*

#### The problem: climate change

The issue of climate change is clearly linked to population size and some scientists have begun to ask whether there are global limits to human habitability.[1128] For example, Dr Steven Running, emeritus professor of ecology at the University of Montana and a member of the NASA Earth Observing System, argues that a population cannot grow indefinitely in a finite ecosystem, such as the Earth. He explains: 'Systems ecology theory predicts

[1125] Valentina Romei (2026) Five ways demographics are transforming the world economy, *Financial Times,* 6 March; https://www.ft.com/content/152766ba-072d-4f5d-948e-d60f93e406d1
[1126] https://www.pensionpolicyinternational.com/why-an-aging-population-doesnt-spell-economic-doom/
[1127] https://www.professionaladviser.com/news/4047456/flexi-retirement-trend-emerges-thirds-plan-research
[1128] How much climate change is due to human intervention and how much is natural has not yet been resolved. For a discussion of this point, see: https://www.theepochtimes.com/epochtv/climate-alarmism-the-distortion-of-data-using-computer-models-facts-matter-exclusive-5662584; and M. Beenstock, Y. Reingewertz, and N. Paldor (2012) 'Polynomial Cointegration Tests of Anthropogenic Impact on Global Warming', *Earth Syst. Dynam*., 3, 173–188, www.earth-syst-dynam.net/3/173/2012/, doi:10.5194/esd-3-173-2012

when resource limits are exceeded, a progressive system feedback of starvation, predation and disease limits uncontrolled population and consumption growth. The global human population has nearly tripled since 1950, and economic activity increased tenfold, leading many to suggest that humanity is heading toward a population and consumption overshoot and correction this century. The global population, currently at [8]bn people, is projected to rise beyond 10bn by 2100. Future limits become an urgent policy issue when one considers the expansion in living standards aspired to by the underdeveloped world. Is humanity smart enough to anticipate global overshoot, and shift to sustainable policies before these morally unacceptable systems feedbacks take over?'.

The core metric for quantifying total plant growth is net primary production (NPP), measured in kilograms per hectare of plant biomass. Land-based plants absorb around 30% of the carbon dioxide that human activity adds to the atmosphere. Increasing NPP slows down global warming. NASA has been monitoring global NPP for the last quarter century. Running points out that NPP depends on temperature and water availability: 'rising temperatures increase growing season length, but decrease water availability, and many of the NPP trends identified can be directly attributed to these effects. We showed how significant droughts between 2000 and 2009 caused the reduction in NPP in the Southern Hemisphere. Decreases in cloud cover increased sunlight over tropical areas causing the largest increases in NPP, particularly in the Amazon rainforest. It initially appeared that rising global temperatures were having a positive effect on the growth of plants, potentially increasing their ability to act as a sink for excess carbon dioxide produced by human activity. However, the reduction in NPP from 2000 to 2009 from drought effects raises serious issues. If rising global temperatures reduce plant growth, the ability of vegetation to act as a carbon sink will be reduced, accelerating climate change'. He concludes: 'As the Earth's population continues to increase, and climate continues to change, consistent monitoring of NPP will become an even more essential tool for understanding and mitigating damage caused to the biosphere. It is essential for humanity to not reach catastrophic planetary limits risking collapse. There is no better and available global dataset than NPP, the foundation of food, fibre, biofuel and climate stabilization, for this essential monitor of global habitability'.[1129]

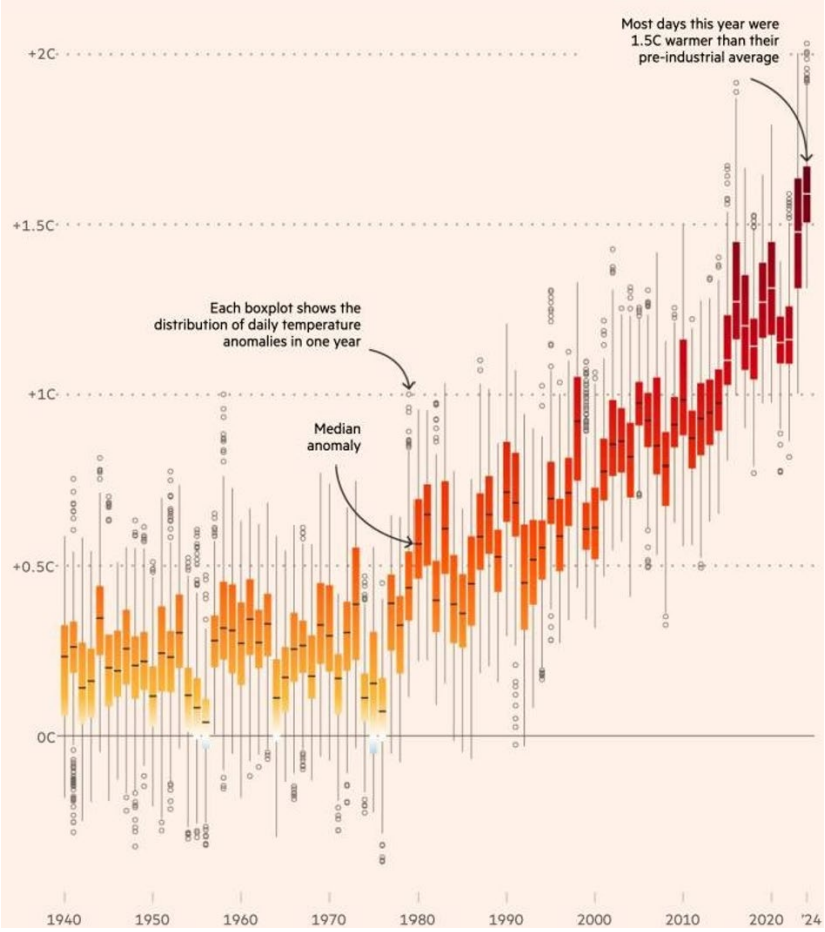
According to the World Meteorological Organization, hydrological cycles are 'spinning out of balance' and the world will experience an 'increasingly erratic' water cycle as climate change drives new patterns of both extreme flooding and drought. Droughts, extreme rainfall and melting snow and glaciers are threatening long-term water security. Petteri Taalas, WMO secretary-general, said that the overwhelming majority of disasters are water related: 'A warmer atmosphere holds more moisture. We are seeing much heavier precipitation episodes and flooding. And at the opposite extreme, more evaporation, dry soils and more intense droughts'.[1130] Between June-August 2023, the Earth experienced the hottest three-month period on record with an average global temperature of 16.7ºC –

[1129] Steven Running (2019) The biosphere: Global limits of human habitability, 30 October; https://www.openaccessgovernment.org/biosphere-human-habitability/75469/

[1130] Quoted in Aime Williams (2023) Global water cycles are 'spinning out of balance', weather agency reports, *Financial Times*, 12 October; https://www.ft.com/content/a8c1b4cb-e7ec-4dd7-9eac-8adc2d874a96

see Figure 11. In September 2023, António Guterres, Secretary General of the United Nations, said that 'Climate breakdown has begun'. The UN forecasts that by 2050, more than 75% of the global population could be affected by drought and lack access to water, up from 1.1bn currently.[1131]

**Figure 11: Global surface air temperature, 1940-2024**




Source: ERA5, C3S/ECMWF. Note: The figure shows the average daily surface temperature compared with the pre-industrial average (1850-1900). Blocks show the interquartile range; https://www.ft.com/content/fd914266-71bf-4317-9fdc-44b55acb52f6

The World Economic Forum's *Global Risks Report 2019* warned of increasing naturally emerging infectious disease pandemics and risks posed by revolutionary new biotechnologies, claiming that these could be as big a threat as climate change.[1132] And within a year this came to pass.

A study by Carlson et al (2022) asserts that at least 10,000 virus species have the capacity to infect humans, but, at present, the vast majority are circulating silently in wild mammals.

[1131] Quoted in Verity Bowman and Harriet Barber (2023) The world has experienced its hottest ever three-month period, *Daily Telegraph*, 13 September; https://www.telegraph.co.uk/global-health/climate-and-people/climate-change-global-warming-wildfires-drought-floods/

[1132] https://cirmagazine.com/cir/epidemic-risks-pose-as-big-a-business-threat-as-climate-change.php

However, climate and land use change will produce novel opportunities for viral sharing among previously geographically-isolated species of wildlife. In some cases, this will facilitate zoonotic spillover between species – a mechanistic link between global environmental change and disease emergence. The study uses a phylogeographic model of the mammal-virus network to simulate potential hotspots of future viral sharing and to make projections of geographic range shifts for 3,139 mammal species under climate change and land use scenarios for the year 2070. The model predicts that species will aggregate in new combinations at high elevations, in biodiversity[1133] hotspots, and in areas of high human population density in Asia and Africa, driving the novel cross-species transmission of their viruses an estimated 4,000 times. Because of their unique dispersal capacity, bats account for the majority of novel viral sharing, and are likely to share viruses along evolutionary pathways that will facilitate future emergence in humans. The study also conjectures that this ecological transition may already be under way, and holding warming under 2°C within the century will not reduce future viral sharing. The authors conclude that 'Our findings highlight an urgent need to pair viral surveillance and discovery efforts with biodiversity surveys tracking species' range shifts, especially in tropical regions that harbor the most zoonoses and are experiencing rapid warming'. Vector-borne diseases (which are caused by the bite of infected insects, such as mosquitoes, ticks, and sandflies, which act as carriers or 'vectors') account for more than 17% of all infectious diseases, leading to more than 700,000 deaths annually.[1134] In March 2024, the first mammal-to-human H5N1 (bird flu) virus transmission took place between a cow and a Texan dairy worker; all previous transmissions to humans came from infected birds.[1135] Live traces of H5N1 were found in batches of raw or unpasteurized milk sold at retail stores in California in November 2024.[1136] The first reported human death from H5N1 occurred in Louisiana on 6 January 2915.[1137]

Some scientists predict a new 'pandemic age'. Professor Eddie Holmes, an evolutionary biologist and virologist at the University of Sydney, said: 'Climate change and pandemics go hand-in-hand….The more animals are forced to mix, the more viruses will jump species'.[1138] One current example is the spread of dengue – or 'breakbone fever' because of the intense joint and muscle pain it causes – by mosquitos. It affected nine countries in the 1970s, but has spread to more than 100 and affects around 400 million people a year. The main causes are climate change and rapid urbanisation.[1139] Another example is mpox (monkeypox) which causes miscarriage, has a fatality rate of up to 10%, and is spreading

[1133] Biodiversity refers to the 8.7m varieties of life forms on Earth, such as plants, bacteria, animals and humans; https://education.nationalgeographic.org/resource/biodiversity/
[1134] Nicola Oliver (2023) The Impacts of Climate Change on Mortality, *Life Risk News*, 8 March;https://liferisk.news/the-impacts-of-climate-change-on-mortality/
[1135] https://www.telegraph.co.uk/global-health/science-and-disease/first-mammal-to-human-transmission-h5n1-bird-flu-confirmed
[1136] https://www.telegraph.co.uk/global-health/science-and-disease/h5n1-bird-flu-raw-milk-california-united-states-of-america/
[1137] https://www.cdc.gov/media/releases/2025/m0106-h5-birdflu-death.html
[1138] https://www.telegraph.co.uk/global-health/science-and-disease/hotter-sicker-climate-crisis-will-trigger-surge-spillover-events
[1139] https://www.telegraph.co.uk/global-health/science-and-disease/why-singapore-alert-record-breaking-year-disease

rapidly in central Africa and could spread to Europe.[1140] In August 2024, the World Health Organization declared mpox a global health emergency.[1141] In October 2024, an outbreak of Marburg – related to Ebola and with a fatality rate of up to 88% – occurred in Rwanda, killing more than a dozen people.

Also in October 2024, the Global Preparedness Monitoring Board (GPMB) – an independent body convened by the Director-General of the World Health Organisation and the President of the World Bank – warned that the next pandemic will probably 'catch the world napping', despite all the advances made during Covid-19: 'Changing patterns of life and the ongoing encroachment of human activities into natural environments [are] altering the global risk landscape and making the emergence of new pathogens more likely'. The GPMB made three critical recommendations to governments focusing on pandemic planning: prioritise risk profiles and assessments that account for a broad range of factors, including those like conflict or climate change that drive up the risk of new epidemics emerging, or those that will impact the world's ability to respond, such as digital connectivity and biomedical innovation; prioritise equity in their preparedness plans, making sure they 'address the specific and basic needs of vulnerable populations', and, in particular, access to 'medical countermeasures', like vaccines or treatments; and for collaboration between different sectors to be strengthened. The GPMB also identified 15 risk drivers, with four having the greatest impact: the movement of people around the world 'is at a record high and is likely to continue to increase in the coming years'; a dramatic increase in global livestock numbers is driving the spread of H5N1; the rise of social media means people are increasingly being exposed to misinformation, and 'public health organizations and governments are struggling to keep up'; and a 'decline in trust in many countries, distrust in institutions is growing and trust in the multilateral system is at risk. This is impacting our collective capacity both to tackle health emergencies and to find multilateral solutions to protect the world'.[1142]

Bowman and Barber (2023) point out that: 'Many [existing] infectious diseases are climate sensitive and global warming is giving them the opportunity to expand their reach, threatening the lives of millions. With flooding, population displacement and overcrowding caused by storms and extreme flooding, waterborne infections – such as cholera, typhoid and hepatitis – are on the rise. Milder winters, warmer summers, and fewer days of frost are also making it easier for disease-carrying mosquitoes to roam beyond their habitats, bringing infections like malaria[1143] [and] Zika …fever closer to countries previously out of their reach'. In August 2025, the European Centre for Disease Prevention and Control (ECDC) reported that deadly and debilitating mosquito-borne diseases are

[1140] https://www.telegraph.co.uk/global-health/science-and-disease/new-strain-of-mpox-causing-miscarriages-spreading-rapidly
[1141] https://www.nytimes.com/2024/08/14/health/mpox-who-emergency-africa.html
[1142] https://www.telegraph.co.uk/global-health/science-and-disease/why-the-next-pandemic-may-catch-us-napping-despite-all-weve/
[1143] The parasite that causes malaria has a complicated life cycle and is able to avoid detection by the immune system. However, two malaria vaccines for children – one developed by GSK and the other by Oxford University – have recently been approved by the World Health Organization; *Telegraph World*, 3 October 2023.

becoming the 'new normal' in Europe. These include West Nile Virus, which can cause serious brain and spinal cord inflammation, and chikungunya, which can lead to long-lasting disability.[1144]

Similarly with fungi. The high body temperature of humans has traditionally protected them against fungi, but fungi are beginning to adapt to higher temperatures, making transmission easier. An example is Candida auris (C.auris), a fungus that first appeared in humans in 2009.[1145] A study by Denning (2024) found that four million people have been dying annually from fungal infections, including chronic pulmonary aspergillosis, pneumocystis pneumonia and cryptococcal meningitis. This is nearly double the previous global estimate and means that fungal infections are killing six times more people than malaria and nearly three times as many as tuberculosis.[1146] In September 2025, the European Centre for Disease Control (ECDC) reported that drug- and disinfectant-resistant C.auris was spreading rapidly in European hospitals, with 4,000 people infected in Europe between 2013-2023. It kills nearly 60% of people who contract it within 90 days, from infections in the blood, brain, spinal cord, bones, ears, and respiratory and urinary systems.[1147]

A report on climate change and health published in December 2020 by *The Lancet*[1148] estimates that global warming has already caused a 50% increase in heat-related deaths of people older than 65, especially in Japan, China, India and parts of Europe. The main reasons for this are heat stroke, kidney failure (caused by kidneys overworking due to dehydration), and heart failure (caused by an excessive heart rate as the heart pumps more blood to the skin, with a corresponding reduction of blood flow to the brain).[1149] In the US, the report argues that rising temperatures, combined with pollution and wildfires, are endangering the health of Americans, with fatal consequences for many older people. The solution, according to the reports' authors is to aggressively curb planet-warming gases in the next five years: 'Climate action is a prescription for health'. In February 2024, a study from the Yale School of Public Health, published in *Nature Communications*, estimated that at 1.5°C, 2°C, and 3°C increases in global warming, heat-related deaths will increase by 0.5%, 1.0%, and 2.5%, respectively. Of these, 20-25% can be attributed to population aging.[1150] In May 2024, an article also published in *Nature Communications* by scientists from the CMCC Foundation–Euro-Mediterranean Center on Climate Change and Boston

[1144] https://www.telegraph.co.uk/global-health/science-and-disease/outbreaks-of-tropical-diseases-becoming-europe-new-normal/
[1145] Verity Bowman and Harriet Barber (2023) The world has experienced its hottest ever three-month period, *Daily Telegraph*, 13 September; https://www.telegraph.co.uk/global-health/climate-and-people/climate-change-global-warming-wildfires-drought-floods/
[1146] David W. Denning (2024) Global incidence and mortality of severe fungal disease, *The Lancet Infectious Diseases*; https://www.thelancet.com/journals/laninf/article/PIIS1473-3099(23)00692-8/fulltext
[1147] https://www.telegraph.co.uk/global-health/science-and-disease/drug-resistant-fungus-spreads-rapidly-in-european-hospitals/
[1148] Reported in the *New York Times*, 3 December 2020.
[1149] https://www.telegraph.co.uk/global-health/climate-and-people/climate-change-global-warming-wildfires-drought-floods
[1150] https://medicine.yale.edu/news-article/aging-population-to-be-major-driver-of-future-climate-related-deaths/; https://www.nature.com/articles/s41467-024-45901-z

University predicted that 246 million people around the world may be at risk of heat exposure by 2050 due to global warming and an aging population.[1151] Also in May 2024, the World Heart Federation (WHF) warned that air pollution was now the 'greatest single environmental health risk', responsible for annual global deaths of 7 million people, around half of which are due to cardiovascular conditions such as heart attacks and strokes. However, it also warned that measures to make homes better insulated and eco-friendly could actually increase the number of deaths by making them airtight and increasing the build-up of air pollutants.[1152] In August 2024, an Air Quality Life Index (AQLI) study published by the Energy Policy Institute (EPIC) at the University of Chicago estimated that permanently cutting fine particulate matter (known as PM2.5) which gets into the lungs and bloodstream would add around two years to life expectancy.[1153]

In 2022, the UK Longevity Science Panel published a report (*The Effects of Climate Change on Health in the UK*) assessing the impact of climate change on the UK's health.[1154] The report suggests that climate change will be experienced unevenly across different sections of the UK population, and may deepen health inequalities in physical and mental health in the UK. The most economically deprived and those who are already frail through age or having long-term health conditions will be the most vulnerable to high temperatures and shocks induced by adverse weather events. Compared with many other countries, the report found that the direct impacts of climate change such as heat waves, flooding and the increased spread of vector-borne diseases, are likely to be relatively modest. This is because of the UK's geographic location in the Northern hemisphere and its economic power to adapt houses, workplaces and infrastructure to reduce the negative impact of climate change.

In March 2025, a study from the USC Leonard Davis School of Gerontology indicated that greater exposure to extreme heat may accelerate biological aging in older adults. The evidence was that people living in areas experiencing more days of high heat showed greater average biological aging than residents in cooler areas. The study was based on 3,600 Health and Retirement Study (HRS) participants aged 56 and older. Blood samples taken during the six-year study period were analyzed for epigenetic changes via a process called DNA methylation. The researchers used epigenetic clocks to analyze methylation patterns and estimate biological ages at each point a blood sample was taken. They then compared participants' changes in biological age to their location's heat index history and number of heat days reported by the National Weather Service from 2010 to 2016. The analysis revealed a significant correlation between areas with more days of extreme heat and individuals experiencing greater increases in biological age. This correlation persisted

[1151] https://www.pensionpolicyinternational.com/up-to-246-million-older-people-may-be-exposed-to-heat-risk-by-2050-due-to-global-warming/
[1152] https://www.telegraph.co.uk/news/2024/05/24/net-zero-efforts-could-cause-rise-in-air-pollution-deaths/
[1153] https://www.telegraph.co.uk/global-health/climate-and-people/cutting-pollution-may-add-two-years-to-average-persons-life/
[1154] https://www.pensionpolicyinternational.com/climate-change-poses-a-threat-to-health-equality-in-the-uk-the-longevity-science-panel-report/

even after controlling for socioeconomic and other demographic differences, as well as lifestyle factors such as physical activity, alcohol consumption and smoking.[1155]

However, the indirect impacts could worsen existing inequalities in health for the following reasons:

- Socio-economic. When economies are stressed the health of the most disadvantaged is disproportionately affected.
- Climate change-related disruptions to global food production and supply chains will reduce food security, particularly for low-income families. Lower socio-economic households are more likely to be exposed to the damage caused by extreme weather events as poverty tends to force people to live in higher risk areas, but they often lack the disposable income to adequately prepare for the hazards associated with climate change. The build quality of certain lower income and private rental homes can make them more vulnerable to severe damage during adverse weather events.
- Gender inequalities. Women are likely to be impacted more by climate effects than men. They are more often the primary caregivers, and these responsibilities can be considered an additional source of stress in times of adversity, particularly when infants and children in their care are threatened directly by displacement or food insecurity.
- Age inequalities. The young and the old are disproportionately affected by climate change compared to working age adults. This is due to differences in physiology, impacts on education, development, exposure, vulnerability to illness, lack of social support, declining health, and disruption to daily activities.
- Mental health. Climate change can negatively impact mental health in two main ways: by causing actual harm to people, family members, homes, livelihoods or culture, or by acting as a threat of harm and source of uncertainty.
- Disruptions to the UK economy, in part caused by climate-induced global economic stresses, are a key indirect pathway through which climate change may adversely impact on population health in the UK.

On the other hand, humans can adapt to climate change as a study by Walkowiak et al (2025) shows. The authors analyzed 22 years of heat mortality in Europe and found that adaptation is outpacing climate change, with Europeans gaining 'the capacity to tolerate an additional 1 °C rise every 17.9 years'. The authors commented: 'Current predictions of climate change impacts rely on conservative assumptions about a lack of adaptation, projecting significantly increased heatwave mortality. However, long-term studies have shown a decline in actual heatwave deaths, raising questions about the underlying mechanisms. …Additionally, increasing economic output, likely driven by infrastructural improvements, especially greater affordability of air conditioning, enabled tolerating each

[1155] https://www.pensionpolicyinternational.com/climate-change-may-drive-premature-aging/

additional 1 °C due to a per capita GDP increase of 19.7 thousand euros. Consistently, the increase in cooling energy demand was the strongest in eastern Europe'.[1156]

Climate change can also have a major economic impact on companies and financial markets in the form of supply chain disruptions, reduced worker productivity, damage to corporate infrastructure and the communities in which businesses operate. In the US, weather-related disasters, such as wildfires, flooding and drought, cost $150bn annually, and are happening with increasing frequency, from an annual average of three in the 1980s to 18 in the 2020s.[1157] A study reported in *S&P Global Sustainability Quarterly* in November 2023 analyzed the S&P Global Sustainable1 Physical Risk Exposure Scores and Financial Impact dataset. It examined seven physical climate hazards: extreme heat, water stress, coastal flood, fluvial flood, tropical cyclone, drought and wildfire. It predicted that without adaptation and resilience measures, by the 2050s, the costs to companies exposed to these hazards will average 3.3% p.a. – and up to 28% – of the value of their real assets. The average rises to 6.0% p.a. by the 2090s. Extreme heat was the biggest single hazard: 'If it is too hot, employee health and safety and company operations can suffer. Energy grids can come under pressure as the general population cranks up air conditioning use. Transportation links can be damaged, leading to delays in supply chains'. Particularly badly affected would be datacenters: 'Datacenters are sensitive to extreme temperatures and restricted access to water due to their dependency on heating, ventilating and air conditioning (HVAC) and cooling'.[1158]

Open interest in the Chicago Mercantile Exchange's weather derivatives (i.e., futures and options) contracts, which was below 20,000 contracts in 2019, rose to 200,000 contracts in 2023. The contracts allow speculators to take a position on temperature swings. They also act as a form of insurance by allowing organizations to hedge extreme weather events. They track an index and their value depends on how far the temperature deviates from the monthly average. The CME said: 'They're more popular now because the market has determined that [extreme weather] events are becoming more impactful and more frequent'.[1159]

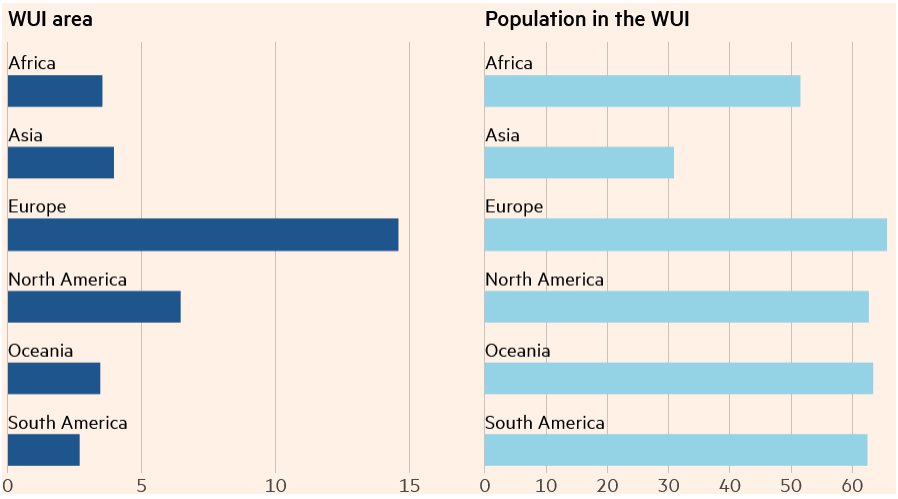
In March 2024, ICE (the Intercontinental Exchange) released a report called 'The link between physical climate risk and sovereign default'.[1160] The report assigned scores to around 200 Sovereigns based on their vulnerability to climate-related deaths, water stress, changes in productivity and temperature. It predicted that Sovereign issuers with the highest exposure to climate risk (with a score of 5) were 18.5% more likely to default than

[1156] Marcin Piotr Walkowiak, Karol Bandurski, Jarosław Walkowiak and Dariusz Walkowiak (2025) 'Outpacing Climate Change: Adaptation to Heatwaves in Europe'. *International Journal of Biometeorology*, 69, 989-1002; https://doi.org/10.1007/s00484-025-02872-0
[1157] https://www.pensionpolicyinternational.com/the-largest-u-s-pension-fund-just-rolled-out-a-climate-transition-plan-focused-on-risk-and-opportunity/
[1158] https://www.spglobal.com/esg/insights/featured/special-editorial/quantifying-the-financial-costs-of-climate-change-physical-risks
[1159] https://www.fnlondon.com/articles/traders-flock-to-weather-derivatives-amid-climate-fears-20240403
[1160] https://www.ice.com/insights/sustainable-finance/the-link-between-physical-climate-risk-and-sovereign-default

those with no physical climate risk exposure (with a score of 0). Each unit increase in the score increases sovereign default probability by 3.7%. The report said that 'under realistic emissions scenarios', the impacts of climate change were likely to have a 'profound' effect on sovereign nations' fiscal stability and economic security. To illustrate, wildfires in 2019 and 2020 cost Australia $100bn.

Figure 12 shows that Europe is particularly at risk of urban wildfires, although most of the world's population lives in wildland-urban interface (WUI) areas. Amsterdam, Athens, Lisbon and Naples are all at risk of extreme weather events, in particular, wildfires and flooding.[1161]

**Figure 12: Wildland-urban interface (WUI) by land mass and population (%, 2020)**



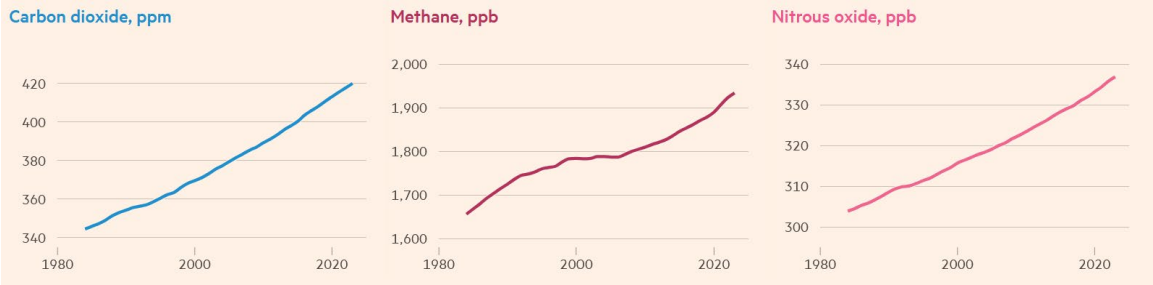

Source: Schug et al (2023)

In March 2025, the UN World Meteorological Organization reported that the concentration of carbon dioxide in the atmosphere was at its highest level in 800,000 years – see Figure 13.[1162]

[1161] Franz Schug, Avi Bar-Massada, Amanda R. Carlson, Heather Cox, Todd J. Hawbaker, David Helmers, Patrick Hostert, Dominik Kaim, Neda K. Kasraee, Sebastián Martinuzzi, Miranda H. Mockrin, Kira A. Pfoch and Volker C. Radeloff (2023) 'The Global Wildland–Urban Interface', *Nature,* 621: 94–99 ; https://doi.org/10.1038/s41586-023-06320-0

[1162] https://www.ft.com/content/36916c9f-377b-4a3a-91d2-62d111faacc8

**Figure 13: Atmospheric concentration by greenhouse gas, 1980-2024**




Source: WDCGG

## The solution: sustainable development

In 2015, the United Nations adopted 17 global Sustainable Development Goals (SDGs), including ending poverty, fighting inequality and addressing climate change.[1163,1164] According to Schroders' 2020 *Global Investment Survey*, 'increasingly clients are using the Sustainable Development Goals as a common language' and estimated global ESG (environmental, social, and governance) assets under management in excess of $1trn.[1165] Investment strategies consistent with SDG include: negative screening (excluding companies based on controversial business practices), socially responsible investing (SRI), thematic (pursuing specific sustainable themes based on a company's operations or sources of revenue) and impact investing (investing in a measurable sustainable outcome in addition to financial returns).[1166]

A related issue is pollution and, in 2013, Dutch inventor Boyan Slat founded The Ocean Cleanup with the aim of removing 90% of floating plastic pollution in the oceans by 2040. There are up to 200 million tons of plastic polluting the oceans, being added to at the rate of 10 million tons a year. Cleanup's system consists of a large floating U-shaped barrier three meters deep which is slowly towed by two ships. Once a week, another two ships collect the plastic which is separated into different recycling streams, packaged, and sent to recycling facilities onshore.[1167]

---

[1163] The UN-commissioned Brundtland Report (*Our Common Future*, Oxford University Press, October 1987) defined sustainable development as meeting the present needs without compromising the ability of future generations to meet their own needs.

[1164] The Global Goals for Sustainable Development: Goal 1: No Poverty; Goal 2: Zero Hunger; Goal 3: Good Health and Wellbeing; Goal 4: Quality Education; Goal 5: Gender Equality; Goal 6: Clean Water and Sanitation; Goal 7: Affordable and Clean Energy; Goal 8: Decent Work and Economic Growth; Goal 9: Industry, Innovation and Infrastructure; Goal 10: Reduced Inequality; Goal 11: Sustainable Cities and Communities; Goal 12: Responsible Consumption and Production; Goal 13: Climate Action; Goal 14: Life Below Water; Goal 15: Life on Land; Goal 16: Peace and Justice Strong Institutions; Goal 17: Partnerships to achieve the Goal; https://www.globalgoals.org.

[1165] The power of measurement: Schroders approach to sustainability, *funds-europe*, November 2020.

[1166] Five reasons to choose indexing for sustainable, *portfolio institutional*, November 2020.

[1167] https://theoceancleanup.com/; https://news.climate.columbia.edu/2022/10/13/how-do-we-clean-up-all-that-ocean-plastic/ https://news.climate.columbia.edu/2022/10/13/how-do-we-clean-up-all-that-ocean-plastic/

**The UK's response**

The UK was the first major country to publish a Green Finance Strategy in 2019.[1168] It agreed to fund a new Green Finance Institute[1169] with the City of London 'to foster greater cooperation between the public and private sectors, create new opportunities for investors, and strengthen the UK's reputation as a global hub for green finance' and a new Centre for Greening Finance and Investment (CGFI) 'to advise lenders, investors and insurers [in order to] enable them to make environmentally sustainable decisions, and support a greener global economy'.[1170] In September 2021, the UK government issued its first 'green gilt' to investors in order to finance projects with clearly defined environmental benefits, thereby helping the UK achieve net-zero carbon emissions by 2050. The bond satisfies the International Capital Market Association (ICMA) Green Bond Principles,[1171] a voluntary framework for issuers to follow and which promotes transparency and disclosure to reduce the risk of 'greenwashing' (where investors are misled about how sustainable an investment is).

The UK government set out 6 categories of expenditure or investment that will be financed by these gilts. Each category is also mapped to appropriate UN Sustainable SDGs:

1. Clean transportation, e.g., zero-emission buses (consistent with the SDG: sustainable cities and communities)
2. Renewable energy, e.g., wind, solar and hydrogen (affordable and clean energy)
3. Energy efficiency, e.g., support schemes for energy efficiency programs for the public, commercial, industrial and residential sectors (including heating, retrofit and insulation) and research and development for new energy efficiency technologies (affordable and clean energy, industry, innovation and infrastructure)
4. Pollution prevention and control, e.g., reduction of air emissions and greenhouse gas control (responsible consumption and production)
5. Living and natural resources, e.g., protection and enhancement of terrestrial and marine biodiversity, ecosystems and natural capital;[1172] sustainable land use and protection, including environmentally sustainable agriculture; environmentally sustainable clean water, water storage and wastewater management initiatives (zero hunger, clean water and sanitation, life below water, and life on land)[1173]

[1168] https://assets.publishing.service.gov.uk/media/643583fb877741001368d815/mobilising-green-investment-2023-green-finance-strategy.pdf
[1169] https://www.greenfinanceinstitute.com/
[1170] https://www.ukri.org/news/10m-research-centre-to-spur-a-greener-global-financial-system/
[1171] https://www.icmagroup.org/sustainable-finance/the-principles-guidelines-and-handbooks/green-bond-principles-gbp/
[1172] Discussed in more detail below.
[1173] Bonds that invest in activities relating to SDG 6 (Clean Water and Sanitation) and SDG 14 (Life Below Water) are known as 'blue bonds'. The market in blue bonds is currently small, with only 26 blue bonds issued between 2018 and 2024 worldwide; https://professionals.fidelity.co.uk/articles/expert-opinions/2024-04-05-blue-bonds-whats-all-comm-ocean-1712297104759;

6. Climate change adaptation, e.g., flood protection, resilience and other risk mitigation programs (climate action).

In March 2023, the UK government published its 2023 Green Finance Strategy, *Mobilising Green Investment*,[1174] aimed at strengthening the rapidly growing global green finance market, while encouraging private investment to deliver its energy security, net-zero and environmental objectives.[1175] One example is direct air carbon capture and storage (DACCS) systems which strip $CO_2$ from the atmosphere and pumps it into disused oil and gas reservoirs under the North Sea which have a total capacity of 78 billion tonnes. In order to meet the UK's net zero commitment, these systems would need to collect 38-48 million tonnes of $CO_2$ annually by 2050. The total cost is estimated at £30bn; the high cost is due to the low concentration of $CO_2$ in the atmosphere, around 426 parts per million, or 0.0426%. The UK is currently responsible for about 800 million tonnes of $CO_2$ annually, half from domestic production and half from imported goods. Globally, around 37bn tonnes of $CO_2$ is produced annually, mainly from using fossil fuels such as coal, gas and oil. Around 40% is absorbed by the sea, while the rest remains in the atmosphere.[1176] In April 2024, JPMorgan released a global energy strategy report which recommended that the short-term focus of the pathway to clean energy should be on the coal to natural gas switch, which could save up to 17% of global emissions compared to a 2022 baseline. Coal made up 44% of global fuel emissions while providing 33% of global fossil fuel energy in 2022.[1177]

**The European Union's response**

In December 2019, the EU introduced the European Green Deal[1178] with the aim of greening both the real economy, especially in agriculture, industry and transport, and its financing through the use of sustainable finance. One of key features of the deal is the Sustainable Finance Action Plan which aims to achieve net zero by 2050.[1179] Another is the Sustainable Finance Disclosures Regulation (SFDR) which requires asset managers to publish disclosure statements about which of their products fall into three distinct categories:

---

https://www.investmentweek.co.uk/news/4321170/fidelitys-atkinson-blue-bonds-growing-popularity-challenges-remain

[1174] This is the first update since 2019; https://www.gov.uk/government/publications/green-finance-strategy

[1175] *XPS Investment Briefing*, September 2021. In September 2021, the European Commission introduced a 'gold standard' for EU 'green bonds' where the proceeds are spent on environmentally friendly activities. The standard came into force in December 2023. European green bonds are aligned with the 'European taxonomy' which specifies the types of green projects that can be funded, making it more difficult for companies to engage in greenwashing; https://www.ipe.com/news/eu-green-bond-standard-rules-to-enter-into-force-after-council-ok/10069660.article.

[1176] https://www.telegraph.co.uk/business/2024/04/28/britain-30bn-strip-co2-atmosphere-hit-net-zero

[1177] https://www.esgdive.com/news/jpmorgan-warns-clean-energy-transition-could-take-decades-or-generations/714180/

[1178] https://www.consilium.europa.eu/en/policies/green-deal/

[1179] https://www.pensionpolicyinternational.com/how-sustainability-disclosures-and-regulations-benefit-investors/

- Article 9 funds: those funds that specifically have sustainable goals as their objective, e.g., investing in companies whose goal is to reduce carbon emissions (known as 'dark green' funds).
- Article 8 funds: those funds that promote E or S characteristics, but do not have them as the overarching objective (known as 'light green' funds).
- Article 6 funds: funds that are not promoted as having ESG factors or objectives (known as 'non-ESG' funds).

A survey by Morningstar (*SFDR – The First 20 Days*) found that Article 8 and 9 funds accounted for around 21% of total European funds and 25% of total European fund assets.[1180]

The main ESG asset classes – which according to S&P Global account for 5% of the total global market – are sustainable investment funds ($500bn) and 'green'[1181] or 'social'[1182] bonds ($500bn). Many of these bonds are issued by inter-governmental organizations (e.g., the EU's SURE[1183] bonds) or local authorities with high credit ratings and they offer higher yields than conventional sovereign bonds. The bonds are used for socio-economic enhancement (30%), housing (21%), education (20%), essential infrastructure (13%) and healthcare (11%).[1184] Europe is the leading region for issuing ESG bonds, with 20% of all European bonds now green, social and/or sustainable. In 2023, 3,184 green social sustainable (GSS) bonds, valued at $930bn, were brought to market.[1185]

Another key feature is the EU's Corporate Sustainability Reporting Directive (CSRD) which requires companies to include sustainability-related information in their annual reports from 2026[1186] that must meet European Sustainability Reporting Standards (ESRS). This will generate considerable amounts of standardised sustainability data in future years, with digital tagging and online repositories aiming to make the data more usable and

[1180] https://esgclarity.com/sfdr-which-groups-have-the-most-article-8-9-funds/

[1181] Green bonds (also known as climate bonds or sustainable bonds) are designated fixed-income bonds intended to encourage sustainability and to support climate-related or other types of special environmental projects. More specifically, they finance projects aimed at energy efficiency, pollution prevention, sustainable agriculture, fishery and forestry, the protection of aquatic and terrestrial ecosystems, clean transportation, clean water, and sustainable water management. They also finance the cultivation of environmentally friendly technologies and the mitigation of climate change; https://www.investopedia.com/terms/g/green-bond.asp

[1182] Social bonds are used to fund projects with positive social outcomes, such as economic development by financing small businesses, affordable housing and transportation, promoting access to education and healthcare in low-income areas, and food supply protection. Traditionally, they have been issued by supranationals and governments. But corporate social bonds are also now being issued by companies wishing to demonstrate their corporate social responsibility to their employees, customers and local communities; https://inews.co.uk/inews-lifestyle/money/ethical-money/social-bonds-what-how-work-available-who-invest-explained-1012606

[1183] Support to mitigate Unemployment Risks in an Emergency (SURE); https://commission.europa.eu/strategy-and-policy/eu-budget/eu-borrower-investor-relations/sure_en

[1184] ESG News, *portfolio institutional*, November 2020 (p26).

[1185] https://www.investmentweek.co.uk/news/4172932/green-social-sustainable-bonds-hit-record-issuance-2023

[1186] https://www.ipe.com/news/eu-parliament-writes-two-year-delay-into-esg-reporting-rules/10071260.article

discoverable. Maurits Heldring, senior adviser for responsible investment at PGGM, said: 'We're looking forward to this data, not just for compliance reasons but also because we are starting what we call 3D investing, covering risk, return and sustainability, and to be able to steer on the third element we need good and consistent data'.[1187] Investment funds are also required to make disclosures under SFDR which will allow investors to compare investment funds and their sustainability performance. An additional key feature is the European Taxonomy Regulation which requires companies to report on the percentage of their economic activities that are environmentally sustainable.[1188] On 31 July 2023, the European Commission released an initial batch of 12 European Sustainability Reporting Standards (ESRSs) developed by the European Financial Reporting Advisory Group (EFRAG). The EU has adopted a double 'materiality approach', implying companies must consider both the impact of a sustainability topic, such as climate, on their activities and the impact of their activities on that topic.[1189] In April 2024, the EU Corporate Sustainability Due Diligence Directive (CS3D) came into effect, requiring firms to undertake environmental and social due diligence on businesses within their value chains, and to mitigate any harms they identify during that process; they also have to develop and implement climate transition plans.[1190]

In December 2023, the European Securities and Markets Authority (ESMA), the EU financial regulator, issued guidelines for funds claiming to contribute to sustainability objectives, including the climate transition. Funds with 'ESG'-related names should allocate at least 80% of their assets in line with their stated strategy, consistent with sustainable investments definitions in Article 2(17) SFDR, and reflecting the expectation investors may have based on the fund's name. The funds must also abide by exclusions developed for Paris-aligned Benchmarks (PABs), screening out companies involved in controversial weapons and tobacco, as well as those deemed to have breached the UN Global Compact or the OECD Guidelines for Multinational Enterprises. In particular, PABs ban investments in companies that generate more than 1% of revenues from coal and lignite, 10% from oil, or 50% from gas, and in companies that generate more than 50% of their revenues from carbon-intensive electricity. At the same time, ESMA has made allowance for funds marketed as contributing to the climate transition, as well as those pursuing social or governance-related objectives. For funds with 'transition'-related names, there is a new category with exclusions based on the EU's Climate Transition Benchmarks, which are less strict than PABs, and allow investments in fossil fuels. ESMA requires such funds, as well as funds with 'impact'-related names, to demonstrate that their investments 'are made with the intention to generate positive, measurable social or

[1187] https://www.ipe.com/special-reports/investors-await-influx-of-standardised-corporate-sustainability-data/10076570.article
[1188] https://www.sustainable-investment.com/opinion/4077463/european-green-deals-framework
[1189] https://www.ipe.com/news/eu-sustainability-board-under-pressure-to-finalise-materiality-guidance/10068505.article
[1190] https://www.ipe.com/news/corporate-sustainability-due-diligence-directive-final-text-gets-green-light/10072891.article

environmental impact alongside a financial return or are on a clear and measurable path to social or environmental transition'.[1191]

Dai et al. (2023) found that, using a broad sample of international investment funds, the introduction of SFDR was followed by a significant decarbonization (around 10%) of investment portfolios of EU-marketed funds claiming to invest based on sustainability criteria. The lower level of emissions was mainly due to changes in funds' investment decisions, but a substantial part of the effect (roughly one third) was due to changes in firm-level emissions. Overall, the findings suggest that regulating investor disclosure induces asset managers to decarbonize their portfolios not only by shifting capital flows away from high-emission firms, but also by increasing pressure on portfolio firms to achieve emissions reductions at the firm level.[1192]

In February 2024, ESMA warned that investment funds claiming to support the 17 UN Sustainable Development Goals could be mis-selling in the form of greenwashing or impact-washing.[1193] It examined 187 funds, with total assets under management of €74bn, which claimed – via their names, investment strategies or Key Information Documents – to contribute to the goals. It then compared the assets against a number of benchmarks, including an SDG Index developed by the UN. It found that, regardless of the different frameworks used for measurement, the 187 funds do not, on average, hold significantly more SDG-aligned issuers. ESMA said 'This raises questions as to whether funds claiming to contribute to the SDGs are actually fulfilling their promise to investors… and that further monitoring was necessary'.[1194] In the same month, the EU announced that ESG rating providers would be authorized and supervised by the ESMA. They would be required to adhere to transparency requirements regarding methodologies and information sources. The new rules also require the detailed disclosure of ESG rating methodologies by financial advisers using ESG ratings in marketing.[1195] Also in February, a survey conducted by MainStreet Partners, a subsidiary of AllFunds, found that 24% of Article 8 funds carried a risk of greenwashing.[1196] In July 2024, ESMA published Guidelines on Enforcement of Sustainability Information (GLESI) which lists its guidelines for promoting convergent and consistent supervision and enforcement by national competent authorities of sustainability information.[1197]

---

[1191] https://www.ipe.com/news/eu-watchdog-spells-out-rules-for-transition-labelled-funds/10070714.article
[1192] Jiyuan Dai, Gaizka Ormazabal, Fernando Penalva, and Robert A. Raney (2023) 'Imposing Disclosure on Investors that Choose to Promote Sustainability: Does it Lead to Portfolio Decarbonization?', European Corporate Governance Institute: Finance Working Paper 945/2023 and IESE Business School Working Paper No. 4564890; https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4564890
[1193] Impact-washing occurs where bonds are labelled as 'impact', but there is little evidence that the issuer uses the proceeds for any demonstratable impact; https://www.funds-europe.com/impact-washing-is-a-reality-amid-growing-issuance-study-finds/
[1194] https://www.ipe.com/news/esma-study-finds-sdg-labelled-investment-funds-risk-impact-washing/10071466.article
[1195] https://www.funds-europe.com/eu-legislators-reach-consensus-on-overseeing-esg-ratings-providers
[1196] https://www.funds-europe.com/quarter-of-article-8-funds-at-risk-of-greenwashing
[1197] https://www.esma.europa.eu/sites/default/files/2024-07/ESMA32-992851010-1600_Final_Report_on_Guidelines_on_Enforcement_of_Sustainability_Information_GLESI.pdf

In February 2024, the EU introduced the world's first carbon removal certification scheme. This allows the trading of carbon removal units (equal to one tonne of $CO_2$ removed from the atmosphere). Four types of carbon removal will be permitted:

- Permanent carbon removals, such as direct air capture and storage and bioenergy with carbon capture and storage (CCS), which can store $CO_2$ for several centuries.
- Temporary carbon storage in long-lasting products such as wood-based construction, for at least 35 years.
- Temporary carbon storage from carbon farming, such as restoring forests and soil, wetland management, seagrass meadows (minimum five years).
- Soil emission reduction obtained from carbon farming, such as wetland management, no tilling and cover crop practises (minimum five years). [1198]

In September 2025, the new Chairman of the Securities and Exchange Commission, Paul Atkins, criticized two EU laws on companies' disclosures of their ESG impacts: the Corporate Sustainability Due Diligence Directive (which requires larger companies to verify whether their supply chains do not use forced labor or cause environmental damage) and the Corporate Sustainability Reporting Directive (which requires companies to disclose information about their ESG impacts to investors and consumers), despite the fact that the EU has watered them down in response to criticisms from some EU members. He said: 'I have significant concerns with the prescriptive nature of these laws and their burdens on US companies, the costs of which are potentially passed on to American investors and customers', adding that the EU should focus on cutting firms' reporting obligations 'rather than pursuing ends that are unrelated to the economic success of companies'. These views reflect the change in US attitudes to financial regulation since President Donald Trump came to office.[1199]

In November 2025, the EU proposed amendments to the Sustainable Finance Disclosure Regulation relating to disclosure reporting and product categories. For the former, the EU proposed to simplify disclosures and delete entity-level requirements for the vast majority of financial market participants in order to remove 'overlaps' with the Corporate Sustainability Reporting Directive. Only the largest market participants would need to disclose their impact on the environment and society. In terms of product categories, the EU acknowledged that the SFDR classification (i.e., Article 6, 8 and 9) had 'effectively been used as a de facto labelling system', which has caused confusion, especially for retail investors, and increased the risk of greenwashing and mis-selling. In place, the EU will introduce three sustainability categories (requiring a minimum of 70% of the portfolio meeting the category criteria): Sustainable (for investments in companies or projects that 'are already meeting high sustainability standards'), Transition (for investments in companies or projects that are not yet sustainable but are on a 'credible transition path' or that contribute towards improvements in sustainability) and ESG basic (for products that

[1198] https://www.euractiv.com/section/climate-environment/news/eu-reaches-deal-on-worlds-first-carbon-removal-certification-scheme/
[1199] https://www.reuters.com/sustainability/boards-policy-regulation/wall-street-regulator-says-it-has-concerns-over-european-esg-rules-2025-09-10/

integrate a variety of ESG approaches but that do not meet the criteria of the other two categories).[1200] In the same month, Morningstar reported that asset managers had stopped launching 'dark green' funds in Europe due to greenwashing fears. According to data from Morningstar, just four Article 9 funds were launched during the third quarter of 2025 — the lowest number rolled out over a three month period since the sustainable investment boom in 2021.

In January 2026, the Joint Committee of the European Supervisory Authorities (ESAs) issued their Final Report on Joint Guidelines to ensure that consistency, long-term considerations and common standards for assessment methodologies are integrated into the stress testing of environmental, social and governance (ESG) risks. The Joint Guidelines have two main objectives which are to: improve the legal certainty, clarity and transparency of the supervisory approval process with regard to the integration of ESG risks into National Competent Authorities (NCAs) stress testing frameworks and scenario analysis frameworks; and ensure consistency, long-term considerations and common standards for assessment methodologies throughout the EU and across sectors.[1201]

**COP26 – November 2021**

In November 2021, COP26, the 26th United Nations Climate Change Conference, took place in Glasgow, Scotland.[1202] The outcome was the Glasgow Climate Pact which:

- Reaffirmed the 2015 Paris Agreement to limit global warming to below 2°C, preferably to 1.5°C, compared with pre-industrial levels and to achieve a climate-neutral ('net-zero') world by 2050.[1203] However, it went further and expressed 'alarm and utmost concern that human activities have caused around 1.1°C of warming to date, that impacts are already being felt in every region, and that carbon budgets consistent with achieving the Paris Agreement temperature goal are now small and being rapidly depleted'.
- Seeks accelerated action to reduce carbon dioxide emissions by 45% in the 2020s, with countries producing stronger national action plans by 2022.
- Agreed to a provision calling for a phase-down of coal power and a phase-out of fossil fuel subsidies.
- Reaffirmed the pledge by developed countries to deliver $100bn a year for developing countries.

[1200] https://www.investmentweek.co.uk/news/4522151/eu-unveils-sfdr-review-trio-sustainability-categories-reporting-reductions
[1201] https://www.eba.europa.eu/sites/default/files/2026-01/60ba0389-2d7a-46b7-96e8-9072c481d8ce/EIOPA-BoS-25-602%20-%20ESAs%20Final%20Report%20-%20Joint%20Guidelines%20on%20ESG%20Stress%20Testing.pdf; https://www.regulationtomorrow.com/france/esas-joint-guidelines-to-ensure-that-consistency-long-term-considerations-and-common-standards-for-assessment-methodologies-are-integrated-into-the-stress-testing-of-esg-risks/
[1202] https://www.un.org/en/climatechange/cop26
[1203] https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

- Called for a doubling of finance to support developing countries in adapting to the impacts of climate change and building resilience.
- Agreed to complete the Paris rulebook, the operational details for the practical implementation of the Paris Agreement. An example is the norms relating to carbon markets, which will allow countries struggling to meet their emissions targets to purchase emissions reductions from other nations that have already exceeded their targets.
- Agreed to strengthen the Santiago Network that connects vulnerable countries with providers of technical assistance, knowledge and resources to address climate risks.
- Agreed new deals on:
    - Halting and reversing forest loss and land degradation by 2030.
    - Limiting methane emissions – one of the most potent greenhouse gases and responsible for a third of current warming from human activities – by 30% by 2030, compared with 2020 levels.
    - Restricting all new car and van sales to be zero-emission vehicles by 2040 globally and 2035 in leading markets, thereby accelerating the decarbonization of road transport, which currently accounts for about 12% of global greenhouse gas emissions.
    - Private financial institutions and central banks realigning $130trn towards achieving global net zero emissions, via the Glasgow Financial Alliance for Net Zero (GFANZ).

GFANZ was established in April 2021 by UN Special Envoy on Climate Action and Finance Mark Carney and the COP26 presidency to accelerate the transition to a net-zero global economy, bringing together CEOs and leaders from the financial services sector.[1204] It supports the UN's Race to Zero campaign and has become an umbrella organization of eight sub-groups, including the Net Zero Asset Owner Alliance, the Net Zero Asset Managers Initiative, and the Net-Zero Banking Alliance.

The International Financial Reporting Standards (IFRS) Foundation announced the formation of the International Sustainability Standards Board (ISSB) at COP26.[1205,1206] It was set up to counter the problem that ESG disclosure was being hindered by differing sets of rules, leading to confusion amongst investors and companies, and hence inaction. It has four key objectives:

- To develop standards for a global baseline of sustainability disclosures.
- To meet the information needs of investors.

[1204] https://www.gfanzero.com/

[1205] The ISSB focuses on investors and the financial markets. The standards published by the ISSB currently only include climate and sustainability, but the board is considering expanding the disclosures to include human capital and rights; https://www.ifrs.org/groups/international-sustainability-standards-board/; https://www.ifrs.org/groups/international-sustainability-standards-board

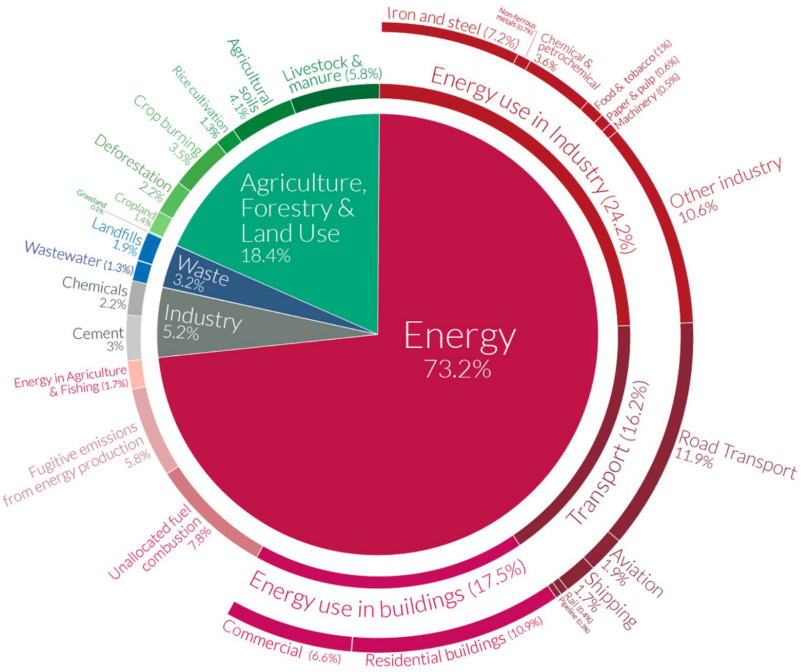
[1206] In 2022, the ISSB took over responsibility for the SASB (Sustainability Accounting Standards Board) Standards for companies reporting on sustainability; https://sasb.ifrs.org/standards/

- To enable companies to provide comprehensive sustainability information to global capital markets.
- To facilitate interoperability with disclosures that are jurisdiction-specific and/or aimed at broader stakeholder groups.

In June 2023, the ISSB published two global corporate sustainability reporting standards: International Financial Reporting Standard S1, the General Requirements for Disclosure of Sustainability-related Financial Information; and IFRS S2, Climate-related Disclosures.[1207] The latter requires greenhouse gas (GHG) emissions to be measured in accordance with the GHG Protocol Corporate Standard (2004), for example.[1208]

Figure 14 shows the sectoral breakdown of global greenhouse gases in 2016.

**Figure 14: Global greenhouse gas emissions by sector, 2016**




Sources: OurWorldinData.org, Climate Watch, World Resources Institute (2020), https://www.visualcapitalist.com/a-global-breakdown-of-greenhouse-gas-emissions-by-sector/

[1207] FRS S1 requires disclosure of all material information about sustainability-related risks and opportunities that could reasonably be expected to affect the entity's prospects (i.e., cash flows, access to finance, or cost of capital) over the short, medium, or long term and is centred around the familiar pillars of: governance; strategy; risk management; and metrics and targets. Value chain coverage is required as well as industry specific disclosures. IFRS S2 is climate specific: it builds on the information required by IFRS S1 and requires additional climate-related disclosures, including GHG emissions data, scenario analysis, transition plan information and certain industry based metrics.

[1208] https://www.ipe.com/issb-releases-robust-inaugural-sustainability-reporting-standards/10067384.article

**Transition planning**

In April 2022, the Transition Plan Taskforce (TPT) was launched by the UK Treasury to develop the 'gold standard for private sector climate transition plans'. The TPT Framework applies three guiding principles: ambition, action (involving implementation and engagement strategies) and accountability (covering metrics, targets and governance). TPT has engaged globally with financial institutions, real economy corporates, policymakers, regulators and civil society to develop its materials. In April 2024, TPT published finalised guidance to help asset owners develop credible climate transition plans. It also published guidance on how entities should approach climate adaptation, nature and the 'just transition' in their climate plans.[1209] TPT said: 'The primary responsibility of asset owners is to secure the financial futures…of their beneficiaries in line with their fiduciary duty (where applicable), contractual obligations and duties imposed by financial regulators. …In order to do this, an asset owner should explain how it integrates climate into its investment decisions, manager selection and contracts, and engagement activities. …Taking a strategic and rounded approach helps asset owners consider a wide range of decarbonization levers available to them and, where possible, avoid a strategy of "paper decarbonization", which is characterized by actions that decarbonize an entity's portfolio in ways that may not necessarily contribute to the actual decarbonization of the economy'.[1210] In June 2024, the IFRS Foundation took over responsibility for transition plan disclosure resources developed by TPT, marking 'an important milestone in the creation of global norms for transition plan disclosure'. The TPT's remaining role was to support the UK's Transition Finance Market Review.[1211]

Transition finance has been defined as 'investments meant to decarbonize high-emitting and hard-to-abate industries such as steel, aviation and shipping. This capital is also aimed at addressing potential social impacts associated with decarbonization, including unemployment and loss of tax revenue for local governments'.[1212] Frédéric Ducoulombier, Research Programme Director at the EDHEC Climate Institute shows that transition finance is one of the three types of investments needed for achieving net-zero:[1213]

- Climate solutions: Investments in activities central to a net-zero economy, including low-emissions energy, clean transportation, energy efficiency and waste management.
- Transition investments: Support for decarbonizing high-emission sectors lacking low-emission substitutes, such as adopting low-carbon processes, retrofitting

[1209] A just transition would involve fairness and equity in the transition to a net zero sustainable economy; https://impact-investor.com/special-report-pension-funds-grapple-with-the-just-transition
[1210] https://transitiontaskforce.net; https://transitiontaskforce.net/wp-content/uploads/2023/10/TPT_Disclosure-framework-2023.pdf; https://www.ipe.com/latest/uk-launches-climate-transition-plan-guidance-for-asset-owners/10072621.article
[1211] https://www.ipe.com/news/ifrs-foundation-takes-over-tpts-transition-plan-disclosure-resources/10074144.article
[1212] https://trellis.net/article/what-transition-finance-and-why-it-matters/
[1213] https://climateimpact.edhec.edu/charting-pathway-transition-finance-lessons-eu-framework

industrial facilities in hard-to-abate sectors….or decommissioning unsustainable fossil fuel power plants and other carbon-intensive facilities.

- Carbon sinks: Investments to offset unavoidable emissions through nature-based or technological solutions, such as restoring ecosystems, enhancing soil and ocean carbon absorption, and advancing carbon capture technologies.

In October 2024, the UK government launched the British Infrastructure Taskforce (BIT) 'as part of a new approach that involves government working with business to design policy that will unlock private investment, including by building business confidence in UK infrastructure investments'.[1214] BIT will offer insights that deliver long-term solutions for job creation, growth, and environmental goals. Members of BIT include PIC, Phoenix Group, M&G, Blackrock, abrdn, the National Wealth Fund (NWF), and IFM Investors.[1215]

IFM Investors has helped to accelerate pension fund investment in Australia's energy transition and wants to do the same in the UK via BIT. It has put forward a number of recommendations that will help enable the right policy settings to drive investment. A key recommendation is resolving the backlog in grid connection requests from renewable power providers, particularly from remote sites as more renewables come online; it is now holding back clean energy development and wider economic growth. Nadeem Hussain, Co-CIO at the £30bn local authority pool LGPS Central, said he would be willing to invest in renewable power providers and data centres, but 'Investors must often bid for grid connectivity years in advance of building the wind or solar development. We ask our managers to ensure the grid connection is secure before we invest because the last thing you want is to cancel a project because there is no grid connectivity. We are [also] open to investing more in data centres but the rapid growth in the sector means many are now securing whatever energy source they can which might not be renewable. We think this is a short-term solution'. Another recommendation is faster planning approvals 'which are essential to nurturing clearer project pipelines and making UK infrastructure more competitive on the global stage', according to Jonathan Ord, head of investments, GLIL Infrastructure. Another recommendation is regulatory certainty. Hussain says 'Infrastructure investors don't want to see a regulatory change that materially impacts the economics of a project during their ownership'. A further recommendation relates to risky investment in large capex projects and early-stage investment in new construction. Luba Nikulina, chief strategy officer at IFM, says: 'Investors require mid-to-long-term power purchase agreements and/or extension of Contracts for Difference terms beyond 15 years to reflect longer project lives. The sharper risks in the next phase of the energy transition in carbon capture, low carbon fuels and floating offshore wind will also require much greater revenue certainty mechanisms. First-of-a-kind projects carry a unique combination of risks, including permitting sites for new technologies, technology maturity and scale,

[1214] https://www.gov.uk/government/news/government-launches-british-infrastructure-taskforce

[1215] IFM Investors is a Melbourne-based investment manager which invests on behalf of institutions worldwide, including pension, superannuation and sovereign wealth funds, universities, insurers, endowment funds and foundations; https://www.ifminvestors.com/en-gb/about-us/

construction and supply chain risks, revenue uncertainty and risks associated with changes to policy and regulation'.

Nikulina hopes to use her seat on BIT to persuade the government to adopt these recommendations: 'successful engagement rests on understanding the government's priorities and finding common ground to crystalise mutual benefits. Open lines of communication and a preparedness for the long haul are key, as well as an understanding that policy makers can't solve risks like inflation and supply chain constraints. I believe we can achieve the best outcomes when we work together and signalling our investment objectives can drive policy change'.[1216]

In January 2022, the McKinsey Global Institute published a report called *The net-zero transition: What it would cost, what it could bring*.[1217] It estimated that capital spending on physical assets for energy and land-use systems in the net-zero transition between 2021 and 2050 would amount to about $275trn or $9.2trn per year. The required spending would be front-loaded, rising from 6.8% of GDP in 2021 to as much as 8.8% of GDP between 2026 and 2030 before falling. The report points out that 'While these spending requirements are large and financing has yet to be established, many investments have positive return profiles (even independent of their role in avoiding rising physical risks) and should not be seen as merely costs. Technological innovation could reduce capital costs for net-zero technologies faster than expected'.

**Pension scheme responses**

## The UK

### Pension schemes

While climate change has been in the news for around 30 years, only in the last few years has it begun to impact the pensions industry. For example, UK listed companies and asset managers, such as pension funds, were required to report on climate change risk by 2022, in line with recommendations made by the Financial Stability Board's Taskforce on Climate-related Financial Disclosures (TCFD).[1218] The UK Pensions Regulator and

[1216] https://www.top1000funds.com/2025/01/meet-the-investors-trying-to-de-risk-uk-transition-infrastructure/

[1217] https://www.mckinsey.com/capabilities/sustainability/our-insights/the-net-zero-transition-what-it-would-cost-what-it-could-bring

[1218] The corporate disclosure recommendations are based on a framework of:

- Governance: the organization's governance around climate-related risks and opportunities.
- Strategy: the actual and potential impacts of climate-related risks and opportunities on the organization's businesses, strategy and financial planning.
- Risk management: the processes used by the organization to identify, assess and manage climate-related risks.
- Metrics and targets: which metrics and targets are used to assess and manage relevant climate-related risks and opportunities.

Department for Work and Pensions have established the Pensions Climate Risk Industry Group (PCRIG) to produce guidance for pension schemes on 'climate-related practices',

---

Pension scheme trustees face similar obligations:

- Governance
  - Trustees must establish and maintain oversight of the climate-related risks and opportunities relevant to the scheme.
  - Trustees must establish and maintain processes to satisfy themselves that any person responsible for the scheme's governance activities takes adequate steps to identify, assess and manage climate-related risks and opportunities.
- Strategy
  - Trustees must, on an ongoing basis, identify climate-related risks and opportunities which they consider will have an effect over the short-, medium- and long-term on the scheme's investment and funding strategy.
  - Assess the impact of the above risks and opportunities.
  - As far as they are able, trustees must undertake scenario analysis, considering the impact on assets and liabilities of two scenarios under which global temperatures rise.
  - One scenario to be consistent with 1.5-2 degrees warming.
  - Analysis is to be carried out in the first year in which the regulations apply, and then every three years thereafter.
- Risk management
  - Trustees must establish and maintain processes for the purpose of enabling them to identify, assess and effectively manage climate-related risks.
- Metrics and targets
  - Trustees must select a minimum of three metrics, two of which are prescribed; one giving total greenhouse gas emissions of the scheme's assets ('absolute emissions metric'), and one giving total carbon dioxide emissions per pound of assets invested ('emissions intensity metric').
  - As far as they are able, trustees must obtain Scope 1, Scope 2 and Scope 3* greenhouse gas emissions data for the scheme's assets, to calculate their metrics and to identify and assess climate related risks and opportunities. (In the first scheme year in which the requirements apply, trustees are not required to collect and report on scope 3 emissions).
  - Trustees must set a target for at least one of the metrics, and subsequently measure performance relative to that target on an annual basis.

*Scope 1: all direct emissions from the activities of an organization or under its control (e.g., business operations).
Scope 2: indirect emissions created from the production of electricity/energy purchased and used by the organization.
Scope 3: all other indirect emissions from activities of the organization (from sources the organization does not directly control, e.g., supply chain or customer emissions when using a company's product).
Sources: https://www.fsb-tcfd.org/; https://www.willistowerswatson.com/en-GB/Insights/2021/09/reporting-pension-scheme-climate-risks-what-how-when

The World Resources Institute has now introduced Scope 4 emissions to refer to the emission reductions that occur outside of a value chain or the life cycle of a product, sometimes called avoided emissions, e.g., the energy or emissions that have been saved as a result of the new climate or energy-saving technology associated with a product or service. Scope 4 emissions also include homeworking emissions, e.g., the emissions created to keep utilities on, laptops running, and to maintain central air conditioning or heating systems; https://greenly.earth/en-gb/blog/company-guide/what-are-scope-4-emissions.

to ensure they are effectively governed in respect of the effects of climate change. Further, asset managers and other financial services firms are required to report publicly on how they manage climate risks.

Speaking at COP26, Thérèse Coffey, the UK secretary of state for work and pensions, said that 'pensions can be a superpower that delivers prosperity for people and the planet in our race to net zero'. Her department launched a consultation on proposals to require occupational pension schemes that already fall within the scope of climate disclosure regulations to publish a 'Paris alignment' metric to show the extent to which their investment portfolio is aligned with the 1.5°C Paris Agreement. The UK government also published *Greening Finance: A Roadmap to Sustainable Investing* which includes a new economy-wide Sustainability Disclosure Requirement (SDR) which would apply to occupational schemes. This aims to tackle greenwashing via the implementation of a Green Taxonomy', which will set out clear criteria for economic activities to meet in order to be considered sustainable. The Pension Schemes Act 2021 introduced new climate reporting obligations on UK schemes, together with annual implementation statements in respect of scheme assets.

The UK Pensions and Lifetime Savings Association (PLSA) which represents pension funds in the UK also supports the TCFD recommendations as well as measures to increase climate reporting and regulatory obligations throughout the investment chain, together with clarifying definitions of climate-aware investment. Related to this is ESG which are the three central factors in measuring the sustainability and societal impact of an investment in a company or business. In the UK, this is implemented via the Stewardship Code. The PLSA wants to work with the investment industry and regulators to develop principles for ESG asset management funds to adhere to on ESG generally, or specifically with regard to climate.[1219]

Sustainability reporting (or sustainability disclosure) of non-financial performance data relating to ESG was first developed by the Global Reporting Initiative (GRI) in 2000. The Global Sustainability Standards Board (GSSB), set up in 2016, is responsible for setting globally accepted standards for sustainability reporting. The GSSB operates to oversee the development of the GRI Standards 'according to a formally defined due process'. The GRI Standards allow third parties to assess the environmental impact from the activities of a company and its supply chain. The Universal Standards for reporting came into effect in January 2023.[1220]

In November 2021, the UK Pensions Regulator published a climate adaptation report into the climate risks most relevant to occupational pension schemes which found that too few schemes were giving enough consideration to climate-related risks and opportunities. Only 43% of defined contribution schemes surveyed took account of climate change when devising their investment strategy, while 51% of defined benefit schemes had not spent

[1219] Richard Butcher (2020) The PLSA is here to help overcome barriers as industry embraces climate-aware investment, *portfolio institutional*, November.
[1220] https://www.globalreporting.org/about-gri/governance/global-sustainability-standards-board/

any time or resources assessing financial risks and opportunities associated with climate change.[1221]

In 2022, a pension consultant offered this advice to trustees considering a net-zero target:[1222]

- Define your beliefs and priorities
- Set your overall net-zero objective
- Review your current portfolio
- Engage with your investment managers and define a net-zero pathway
- Consider sustainable funds
- Establish ongoing engagement and monitoring.

Charles Counsell, TPR's chief executive, said: 'Climate change is a risk to long-term sustainability [that] pension trustees need to consider when setting and implementing investment strategy, while many schemes are also supported by employers whose financial positions and prospects for growth are dependent on current and future policies and developments in relation to climate change'.[1223] In February 2024, the Financial Markets Law Committee, which advises the UK markets on financial law, said pension trustees may consider climate change when making investment decisions, alleviating long-standing concerns that incorporating key ESG factors could be a breach of fiduciary duty – which is to act in the best financial interests of scheme members.[1224]

Ashley Hamilton Claxton, head of responsible investment at Royal London Asset Management, argues that 'ESG is here to stay. Covid-19 has accelerated the trend towards greater awareness of sustainability and the interconnectedness between our economy, environment and society'. However, standards differ in different parts of the world. In the EU, for example, ESG is part of the fiduciary duty of fund managers, whereas in the US, the fiduciary duty is purely a financial duty.[1225]

In February 2022, the UK Employer Covenant Practitioners Association (ECPA) published a report which argued that climate change is 'progressively impacting' the covenant of a range of employers sponsoring DB schemes, from affecting future cashflows to representing a 'fundamental risk' to scheme longevity. The report said that DB schemes should consider the impacts of climate change through sectoral analysis, including

---

[1221] Further climate change disclosures in the offing as world leaders meet at COP26, *XPS Insights*, November 2021.
[1222] Carbon Reduction Pathways: How your pension scheme investments can become Net Zero aligned now, *XPS*, July 2022.
[1223] Susanna Rust (2019) UK to explore mandatory climate reporting for pension funds, companies, *IPE*, 2 July; https://www.ipe.com/uk-to-explore-mandatory-climate-reporting-for-pension-funds-companies/10032058.article. Susanna Rust (2020) UK pension trustees presented with guide to climate-related risks, *IPE*, 12 March; https://www.ipe.com/news/uk-pension-trustees-presented-with-guide-to-climate-related-risks/10044243.article
[1224] https://www.pensionpolicyinternational.com/u-k-pension-funds-may-consider-climate-change-financial-markets-law-committee/
[1225] Romil Patel (2020) Spinning on a sustainable axis, *funds-europe*, November 2020.

technological evolution, in order to identify 'red flags for their sponsor'. It added that covenant practitioners sit in the middle of the impact on the sponsor and the impact on other aspects of the scheme such as funding and investment. They will need to work with an increasing number of stakeholders and face a 'steep' regulatory trajectory.[1226]

In June 2022, the UK Department for Work and Pensions, in collaboration with the Behavioural Insights Team, Aviva, Smart Pension and Hargreaves Lansdown, launched a 'green nudge' trial, designed to encourage pension scheme members to learn more about making greener pension choices. The trial would test the impact of behavioural nudges and messages on increasing saver engagement with the sustainability of pension investments and how it could translate into greener pension decision-making. Around 160,000 pension scheme members were involved. The DWP said: 'Through the productive long term investment power of pensions, we can help the UK get to net zero and deliver both investment returns and a sustainable planet'.[1227] The findings were published in October 2024: general engagement with pensions is low; scheme members were more engaged with the financial performance of their pensions than the environmental performance of the investments and that light-touch communication-based nudges are not a promising avenue to shift pension investments towards more environmentally sustainable funds; and given the low consumer engagement with the sustainability of their pensions, in order to make meaningful progress towards aligning pension investments with environmental sustainability, interventions further upstream would be needed; this will require further research to understand the role of key players including employers, pension providers, trustees and government, in increasing the environmental sustainability of investment funds, with a focus on default arrangements.[1228]

In May 2023, UK consultancy LCP introduced a new tool – LCP Beacon – to help pension scheme stakeholders improve their understanding and engagement with sponsor-related climate risks and opportunities to ensure DB pensions are protected. The tool enables trustees to analyze company business plans and forecasts, linking what was promised to a sponsor's stakeholders around net zero and climate risk mitigation goals and the cost of implementation.[1229] In March 2024, Aon introduced RI-360i, a tool to help institutional investors understand and manage risks, and build responsible investment portfolios. It can help to identify, understand, and effectively manage sustainability issues, such as climate risk, and their impact on investment portfolios. It can also evaluate alternative managers who may align more closely with the investor's objectives on responsible investment.[1230]

---

[1226] https://www.professionalpensions.com/news/4044614/climate-change-fundamental-risk-scheme-longevity

[1227] https://www.pensionpolicyinternational.com/new-uk-trial-seeks-to-nudge-people-into-making-greener-pension-choices/

[1228] *Applying Behavioural Insights to Green Pensions*; https://assets.publishing.service.gov.uk/media/66fbf73de84ae1fd8592ec18/Applying-Behavioural-Insights-to-Green-Pensions.pdf

[1229] https://www.ipe.com/news/lcp-sets-up-climate-risk-tool-for-pension-scheme-stakeholders/10066769.article

[1230] https://www.ipe.com/news/aon-launches-enhanced-responsible-investment-solution/10072350.article

In December 2023, UK consultancy XPS reported that UK pension schemes were still holding assets that were misaligned with the climate transition. It reviewed the Taskforce on Climate-related Financial Disclosures of 35 pension large schemes, with total assets of £344bn. It said that that progress has been made among schemes to manage climate risk, since most schemes had changed their investment mandates to include climate-aware objectives and to finance climate solutions more directly. However, it also said that there was 'room for improvement', since most schemes had focused specifically on carbon emissions reduction, leaving other aspects of climate transition underrepresented. XPS estimates that UK pension schemes' asset holdings have a weighted average of reported Implied Temperature Rise of 2.8°C, whereas the Paris Agreement limits the temperature rise to 1.5°C, explaining XPS's conclusion that UK pension schemes are currently misaligned with the climate transition. The TCFD also requires schemes to stress test the financial impacts of physical risks in a high global warming scenario every three years. The XPS analysis found that 56% of £5bn+ schemes did not conduct the test in 2023 and many that did said that they did not find meaningful conclusions. In the light of these findings, XPS recommends that: scheme trustees undertake ongoing training to understand the latest TCFD developments, speak to their pension consultants on enhancing their climate strategy, assess the transition alignments across their portfolios, and consider increasing range of funds with embedded climate objectives.[1231] In February 2024, a study by sustainability research organization Profundo of the top 20 UK DC workplace pension scheme providers, with combined assets of £500bn, found that 85% had 'inadequate' or 'poor' climate plans in place. Further, despite almost all having publicly set net zero targets, not one provider was deemed to be taking a leadership role on climate action. The main failures related to fossil fuels (coal, oil and gas) and deforestation and land use.[1232]

In October 2025, the 'Sterling 20' group comprising 20 of the UK's largest pension providers and insurers was formed to collectively invest in sustainable regional economic development, affordable housing, infrastructure and modern high-growth industries, such as AI and fintech. The initiative follows the Mansion House Accord in May 2025 in which workplace pension providers committed to invest at least 5% of default fund assets (c£25bn) in UK private markets by 2030. Legal & General pledged £2bn by 2030 to fund 10,000 affordable homes and create 24,000 jobs nationwide, while NEST, which provides pensions for one third of the UK workforce, will invest £500m through Schroders Capital. In addition, AustralianSuper, Australia's largest pension fund, announced a £500m UK living platform focused on rental housing and planned to invest £8bn in the UK over the next five years.[1233]

In December 2025, the Universities Superannuation Scheme (USS) and Transition Risk Exeter issued *The Policy Challenges of the Energy Transition*, which urged asset owners to focus more on collaborating and engaging at a macro level with governments and regulators to help to bring about policy change, rather than spend time on reducing portfolio

[1231] https://www.ipe.com/news/uk-schemes-misaligned-with-climate-transition-says-xps-study/10070610.article
[1232] https://www.ipe.com/news/majority-of-uk-pension-providers-found-to-have-inadequate-or-poor-climate-plans/10071725.article
[1233] https://impact-investor.com/uks-pension-sector-to-drive-sustainable-regional-growth

emissions.[1234] The policy document pointed out that, while the easiest way for investors to reduce emissions from their portfolio investments is to sell high-emitting assets to other owners, this does nothing to advance the low carbon transition or reduce the systemic risk of climate change that threatens all investors' long-term returns. Further, emissions are a lagging indicator. By contrast, investment in renewables, such as solar and wind, is a leading indicator of the low carbon transition. The document argued that 'A fundamental mistake is to assume that any effect on the economy must be marginal, involving only small changes within the existing system, rather than recognising that it is system stability that is at stake. …Only decisive action by governments can substantially reduce these risks and accelerate the growth of the clean energy economy'.

In the UK, this requires specific actions, according to the report:

- Early-stage policies should include support for research and development of new technologies, and measures such as targeted subsidies and public procurement to enable their first deployment.
- In the middle stage of a transition, regulations can be even more powerful in driving the reallocation of investment on a large scale. For example, zero emission vehicles (ZEV) mandates have proven outstandingly effective in growing markets for electric vehicles in California, Canada and China. Yet in the UK, demand for electric cars is constrained by inadequate charging infrastructure and expensive upfront and insurance costs.
- In the buildings sector, the 'clean heat market mechanism' is designed to shift investment from gas boilers to heat pumps, supported by heat pump subsidies. However, this effort is undermined by government levies.
- In the late stage of a transition, a deeper restructuring of markets is often needed to make best use of the new technologies. For example, in the UK expensive gas sets the electricity price 98% of the time, despite generating only 40% of the power.

In March 2026, Smart Pension published a human capital benchmark for its £4.4bn equity fund and provided one of the UK's first comprehensive human capital assessments of a pension fund equity portfolio. The intention is to help create an industry-wide benchmark and bring closer alignment between social factors and climate risk in investment analysis. Smart Pension's underlying research (*Smart Trends: Social Insights*) shows how human capital data (on, e.g., gender, ethnicity and education) can support decision-making and active ownership, while remaining compatible with the pension scheme's legal duties to scheme members.[1235]

In March 2026, NEST, now the UK's largest workplace pension scheme by membership, announced that that it might vote against companies that have materially scaled back their

[1234] https://www.top1000funds.com/2025/12/uss-paper-urges-governments-to-do-more-to-support-climate-policy/

[1235] https://www.ipe.com/news/smart-pension-unveils-uk-first-human-capital-benchmark-for-44bn-equity-fund/10135850.article; https://cdn.prod.website-files.com/5de10f93d41c9b7a31b7c9ca/69a982c42d6ea2f4bfd92391_Smart%20Pension_Social%20Insights_Report.pdf

climate strategies. It said: 'We have engaged – and where necessary, voted against – companies that weaken their climate plans and do not provide adequate transparency to shareholders. We also expect companies to put material changes to their climate strategy or transition plan to a shareholder vote. …Our priority remains safeguarding our members' long-term interests by encouraging responsible management of climate-related risks'.[1236]

In March 2026, People's Pension announced that it had 'moved away from a singular, top-down '1.5°C-aligned portfolio' (limited to no overshoot) target as an investment constraint, emphasising practical, evidence-based action rather than theoretical scenarios or unrealistic expectations of portfolio decarbonisation. People's Pension has found that maintaining portfolio targets that are inconsistent with the real world could significantly increase levels of risk with little real benefit. …We hope that by being open about the uncertainty and complexity, and our approach to it, we can make a constructive contribution to the conversation'.[1237]

### Pension risk transfer providers

SDG/ESG considerations have begun to impact the investments held by PRT providers in the UK. For example, they are investing in social housing. Not only does this meet one of the SDGs, it also provides a regular income stream to pay pension annuitants from an investment that generates higher returns than UK government bonds. Similarly, in March 2022, the Aon MasterTrust and Aon's Group Personal Pension Plan seeded the UBS Global Equity Climate Transition Fund with £700m. The fund offers cost-efficient and broad-based exposure to global equity markets, providing investors with the ability to mitigate climate-related investment risks while aiming to have a positive effect on society.[1238] As another example, in July 2022, Railpen, the UK railways pension scheme, and the Alberta Investment Management Corporation (AIMCo) bought a grid-scale battery energy storage platform in the UK from investment firm Constantine for £400m. Railpen said: 'This acquisition marks Railpen's first direct investment into battery storage and reflects our ambition to drive positive change through our portfolio, working with management to develop the critical infrastructure needed to support the UK's transition to net zero'.[1239]

## The European Union

The EU has had a funding instrument for the environment and climate action, called the LIFE Programme, since 1992.[1240] Since then, it has co-financed more than 6,500 projects aimed at tackling biodiversity loss, reducing emissions, and protecting natural resources.

[1236] https://www.esgtoday.com/nest-to-vote-against-companies-that-have-scaled-back-climate-commitments/
[1237] https://www.ipe.com/news/peoples-pension-drops-15c-portfolio-target-due-to-real-world-inconsistency/10136021.article
[1238] https://www.ipe.com/news/aon-mastertrust-pension-plan-seed-ubs-climate-fund/10058957.article
[1239] https://realassets.ipe.com/news/railpen-aimco-to-pump-400m-into-uk-battery-energy-storage-projects/10061353.article
[1240] https://cinea.ec.europa.eu/programmes/life_en

These projects will help the EU meet its 2050 climate-neutral goal, support green innovation, and enhance citizens' quality of life. The LIFE Programme has also invested in 19 projects addressing the growing impacts of climate change, such as heatwave adaptation, sustainable farming, and carbon capture through peatland restoration. Its budget is managed by CINEA, the European Climate, Infrastructure and Environment Executive Agency. The budget for the period 2021 to 2027 was €5.43bn.[1241]

In December 2020, the European Insurance and Occupational Pensions Authority (EIOPA) published a discussion paper on a methodology for including climate change in the Solvency II standard formula when calculating natural catastrophe underwriting risk.[1242] The frequency and severity of natural catastrophes and extreme weather, such as heat waves, heavy precipitation, droughts, top wind speeds and storm surges, is expected to increase due to climate change. EIOPA wants to ensure the financial resilience of (re)insurers covering natural catastrophes, implying that the solvency capital requirements for natural catastrophe underwriting risk need to be appropriate in light of climate change.[1243]

In April 2022, EIOPA launched its first stress test of the impact of climate change on European pension scheme investments. It included not only an assessment of the effects of a rise in inflation, but also a climate risk stress which will test schemes' resilience against a climate change scenario developed with the European Systemic Risk Board and the European Central Bank. The scenario involves a disorderly transition to climate neutrality due to delayed policy action, specifically, that new climate policies are not introduced until 2030 and this leads to an abrupt carbon price increase which affects the entire economy. The stress test will focus on both the impact on pension fund investments and the financial situation of scheme sponsors.[1244]

In December 2022, EIOPA reported the findings from this stress test. The test covered 187 pension funds from 18 EU member states with €2trn of assets (65% of total assets in DB and DC schemes). The funds were tested for resilience to a sharp rise in carbon prices caused by a sudden disorderly transition to carbon neutrality resulting from delayed policy actions. The funds held 6% of their share and 10% of their corporate bond investments in carbon intensive industries such as mining, electricity, gas and land transport. The stress test resulted in a fall in asset values of 12.9%. EIOPA concluded that the funds were 'materially exposed' to transition risks.[1245]

---

[1241] https://www.innovationnewsnetwork.com/eu-invests-e358m-in-new-life-programme-projects-to-drive-climate-action/63460/

[1242] EIOPA launches discussion paper on a methodology for integrating climate change in the standard formula, *Pensions Policy International*, 4 December 2020; https://pensionpolicyinternational.com/eiopa-launches-discussion-paper-on-a-methodology-for-integrating-climate-change-in-the-standard-formula

[1243] For more details about the impact on insurance of climate risk, see Garrido et al. (2024).

[1244] https://www.ipe.com/news/eiopa-launches-climate-risk-focussed-2022-pension-fund-stress-test/10059031.article

[1245] https://www.pensionpolicyinternational.com/climate-change-could-cost-pension-funds-billions-eu-watchdog-says/

In 2021, the Task Force on Climate-related Financial Disclosures defined the following types of transition risks:[1246]

- Policy (and legal) risk stems from changes in policy regulations (e.g., the European Green Deal, launched in 2019), which aim to promote adaptation and constrain actions that contribute to adverse impacts. For instance, implementing carbon-pricing mechanisms to target the reduction of greenhouse gas emissions, or measures to increase water efficiency for sustainable practices, can result in increased operational costs. These changes can reduce the long-term value of certain infrastructure assets, particularly those that rely on high-carbon activities, leading to 'stranded assets' risks.

- Technology risk arises from emerging technologies and innovations such as renewable energy and carbon capture and storage, which can change the competitive landscape and production/distribution costs of certain organizations, and disrupt parts of the existing business models.

- Market risk refers to shifts in supply and demand for certain products and services, considering both climate risks and opportunities into account.

- Reputation risk arises when public and stakeholder perceptions shift regarding an organization's stance on the transition to a low-carbon economy.

The EDHEC Climate Institute offers a definition of climate risk for investors.[1247] It defines 'climate transition risk as a situation in which climate policies and regulations are introduced late and abruptly, or when technological shocks occur, negatively affecting the performance of fossil fuel and high-carbon firms, and thus the value of their financial contracts. In this context, investors cannot fully anticipate the potential shocks to performance and assets. Losses from stranded assets, which are exposed to fossil fuels, could then cause implications for financial stability (e.g., revenue loss, lower profits, need for higher returns to compensate investors). Therefore, assessing potential financial losses that investors may face is essential to mitigate these risks'. Transition risks are particularly important for infrastructure projects. According to a study by EDHEC Infra & Private Assets,[1248] a disorderly scenario could result in substantial value losses for infrastructure investments, amounting to nearly $600bn by 2050.

[1246] https://scientificratings.com/wp-content/uploads/2025/11/scr_ipe_supplement_nov2025.pdf (Box 2, p.3)
[1247] https://scientificratings.com/wp-content/uploads/2025/11/scr_ipe_supplement_nov2025.pdf (Box 1, p.13)
[1248] Amenc, N., F. Blanc-Brude, B. Jayles, A. Gupta, D. Marcelo and J. Orminski (2023) Highway to Hell: Climate Risks Will Cost Hundreds of Billions to Investors in Infrastructure Before 2050, EDHEC Infra & Private Assets; https://www.edhecinfraprivateassets.com/wp-content/uploads/2023/12/Highway-to-hell.pdf

In February 2024, EIOPA set out four principles that should be observed when insurers and pension entities make sustainability claims:[1249]

- Principle 1 states that sustainability claims 'should be accurate, precise, and consistent with the provider's overall profile and business model, or the profile of its products'. To ensure the accuracy of sustainability claims, all relevant information should be disclosed without omission.
- Principle 2 states that sustainability claims should be kept up to date, and any changes should be disclosed in a timely manner and with a clear rationale.
- Principle 3 states that sustainability claims should be substantiated with clear reasoning and facts. In line with Principle 2, any change to the sustainability profile of a product must be adequately substantiated.
- Principle 4 states that sustainability claims and their substantiation should be accessible and understandable.

In October 2023, the EU adopted the 'Fit-for-55' package which aims to reduce greenhouse gas emissions by 55% by 2030. In November 2024, the EU conducted a 'Fit-for-55' stress test on banks, insurers, investment funds and pension funds, and found that, in the worst-case scenario, the pension funds experienced losses of 21.5%, considerably more than the other three institutions. In this scenario, transition risks manifest themselves in the form of a 'run-on-brown' shocks, whereby investors sell off the securities of carbon-intensive firms, combined with 'other standard macro-financial stress factors'. This results in significant decreases in market values, especially of corporate and sovereign bonds, which constitute around half of insurers' and pension funds' investments. However, the increase in yields reduces pension fund liabilities which helps to ameliorate the negative impact.[1250]

In April 2025, EIOPA launched its fifth stress test of occupational pension funds, assessing the impact of two adverse economic scenarios on the liquidity position of pension funds, in the one case, sharp increases and, in the other case, sharp declines in interest rates. EIOPA said: 'In the "yield curve up" scenario, EU interest rates increase sharply as market participants anticipate economic developments related to the abrupt escalation of geopolitical tensions. These geopolitical tensions cause disruptions in trade and a sharp rise in commodity prices, leading to a large upward revision in inflation expectations. In this context, the scenario assumes EU's vulnerability to trade restrictions that cause the euro to depreciate. In the second, "yield curve down" scenario, EU interest rates plummet as market participants internalise an unexpected prolongation of geopolitical tensions, triggering a loss of confidence in financial markets'. The results were published in December 2025. They confirmed that European occupational pension funds generally had sufficient liquidity buffers to absorb shortfalls. However, a potential liquidity risk was

[1249] https://www.pensionpolicyinternational.com/eu-sustainability-and-greenwashing-in-insurance-eiopa-publishes-draft-opinion
[1250] https://www.ipe.com/news/pension-funds-assets-down-by-up-to-215-in-climate-stress-scenario/10126438.article

identified: the scenarios highlighted that liquidity risks, particularly those arising from margin calls related to derivatives positions, could pose a threat.[1251]

In December 2025, the EU agreed a legally binding target to cut greenhouse gas emissions by 90% from 1990 levels by 2040, allowing up to 5% of the reductions to be met through foreign carbon credits. The deal requires an 85% cut from European industries and keeps the EU on track for net zero emissions by 2050.[1252]

### The US

In January 2024, Matthew E. Kahn, John Matsusaka, and Chong Shu published a study entitled *In Divestment and Engagement: The Effect of Green Investors on Corporate Carbon Emissions* (NBER Working Paper 31791).[1253] The study analyzed whether US public pension funds affect the level of greenhouse gas emissions at the companies they own. It categorized public pension funds based on the political affiliation of the leaders who control them through governance or board trusteeship. Those under Democratic control were labeled 'green', while those under Republican control were labeled 'non-green'. The study's hypothesis was that that Democrats generally favor carbon emission reductions more than Republicans. It analyzed emissions data from 2010–21 for 5,241 facilities across 685 publicly traded companies, along with data on pension fund stock holdings for 24 of the US's 50 largest public funds. These funds collectively managed over 88% of total public pension assets in the US. Companies reduced their greenhouse gas emissions as the ownership stake of green pension funds rose. A 1 percentage point rise in shares owned by green pension funds was associated with a 3.1% decline in carbon emissions over four years, and a 5.2 percentage point increase in the probability of some carbon emission reduction over this period. Increased ownership by non-green funds was not associated with any decline, and may be associated with an increase in emissions. See Figure 15.

The study considered three ways in which increased green ownership could potentially affect emissions: managerial reactions to investor ownership, pressure exerted by investors through shareholder proposals, and persuasion of managers by pension shareholders. It found that emission cutbacks depend in part on the proactive engagement of green funds, suggesting that managers do not respond without some shareholder involvement. It rejected the shareholder proposal channel since it found no increase in shareholder environmental proposals calling for companies to scrutinize and report on environmental concerns after a surge in green ownership. The study concluded that persuasion carries more weight than confrontational pressure in driving emission reduction.

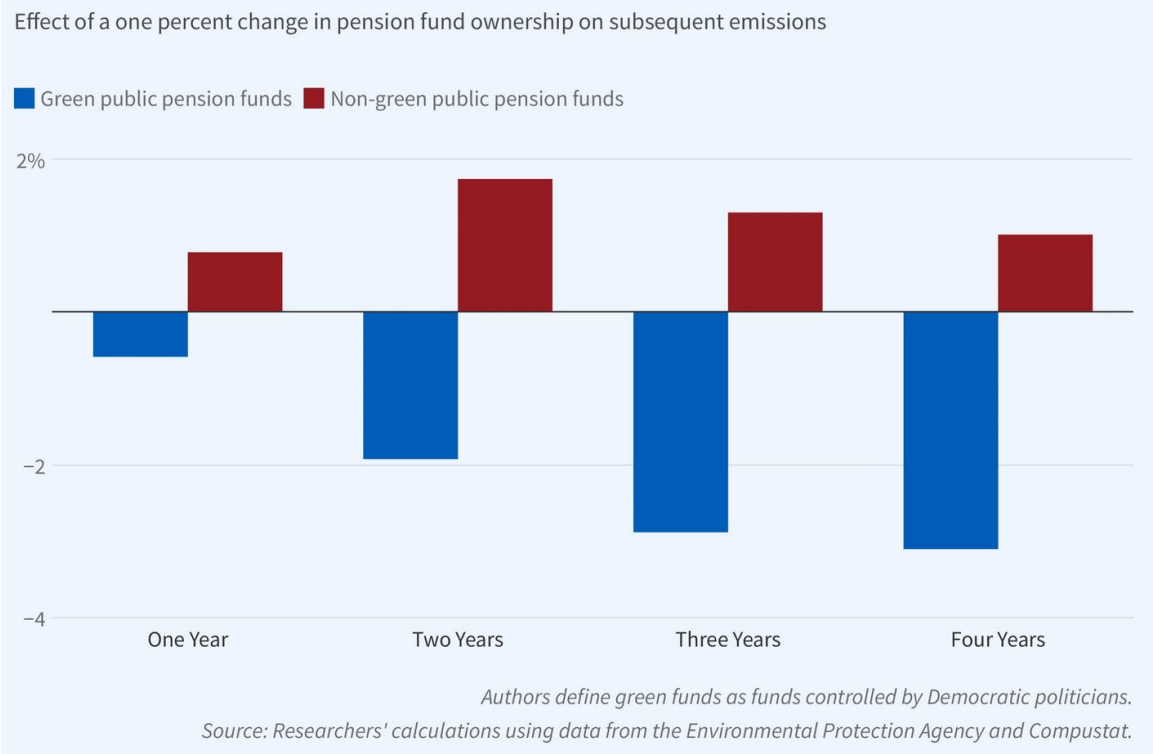
---

[1251] https://www.eiopa.europa.eu/browse/financial-stability/occupational-pensions-stress-test/occupational-pensions-stress-test-2025_en

[1252] https://www.msn.com/en-us/news/world/eu-strikes-deal-on-climate-target-to-cut-emissions-by-90-by-2040/ar-AA1S4eK3

[1253] https://www.nber.org/digest/202401/role-green-investors-reducing-corporate-carbon-emissions; https://www.nber.org/papers/w31791

**Figure 15: Pension fund ownership and corporate greenhouse gas emissions**




In March 2026, a proposed class-action complaint against Cushman & Wakefield and its 401(k) plan fiduciaries alleged a breach of duty not for using ESG factors and for failing to consider climate-related financial risks which claimants claimed to be a ERISA violation. Law firm Cohen Milstein Sellers & Toll called the case potentially 'profound' in its implications for 401(k) plans, since it could establish climate-risk management as a mandatory component of fiduciary duty. However, just prior to this, a US Federal judge's landmark ruling against American Airlines found that fiduciaries violated ERISA by including ESG factors.[1254]

In April 2026, New York City's five public pension funds – covering police officers, teachers, firefighters, etc – announced that they would invest $4 billion (out of a total of $320 billion in assets) in affordable homes developments in the city over the next four years.[1255]

## Global

In November 2024, Ortec Finance published its first global pension fund climate risk report, *Climate Risks Facing the Pension Industry Worldwide*, which analyzed publicly available data from around 140 pension funds in the US, Canada, the UK, the Netherlands

[1254] pionline@e.crainalerts.com, 12 March 2026
[1255] https://www.pensionpolicyinternational.com/us-new-york-city-to-spend-4-billion-from-pension-funds-on-affordable-homes/

and Switzerland using its climate scenario modelling framework. It considered seven climate scenarios, including the climate tipping into high-warming states (involving a global average rise in temperature of 3.7°C). It found that North American pension fund returns could decline up to 50% by 2040 under a high-warming scenario, UK funds by less than 30% by 2040, and Dutch and Swiss funds by much less due to their lower geographical exposure to extreme climate events and substantial allocations to less vulnerable assets. Transition risks are expected to be the dominant climate risk driver compared to physical risks during the 2025–2030 period for pension funds worldwide. A 'disorderly' transition ('drastic and uncoordinated policy changes' designed to reach net zero quickly) would result in average losses of 14% over the next five years. Doruk Onal, climate risk specialist at Ortec Finance, warned that the decline in investment returns has serious implications: 'For pensioners, reduced returns could lead to lower retirement benefits and financial insecurity. Sponsors, including corporations and government bodies, might face increased contributions to cover shortfalls, impacting their financial health. Employees could also be affected by lower pension fund performance, leading to potential adjustments in retirement planning and expectations'.[1256]

In April 2026, Ortec Finance released a report urging global pension funds to assess the physical climate-related risks from investing in private assets, which are typically less liquid and held for much longer than equities or bonds: 'Investments made now into infrastructure or real estate typically have a 15-year plus time horizon, so these are highly likely to be affected by rising physical climate risks'. Ortec Finance estimates private infrastructure assets in the US will suffer a 30% loss in returns over the 15-year horizon, under a limited action scenario where temperatures increase by 2.8°C by 2100. Losses will exceed 60% in a high warming scenario where temperatures increase 3.8°C by 2100. Losses under these scenarios occur as longer-term physical risks begin to be priced into financial markets.[1257]

### Large pension schemes

We consider examples of some large pension schemes' climate change considerations that have been publicly reported.

In May 2024, Japan's Government Pension Investment Fund published a study examining the impact of it engagement program. It used a proprietary dataset of 26,792 engagements across 21 externally managed funds between 2017 and 2022. The study analyzed how asset managers select engagement targets and assess their impact on corporate performance. There were three key findings: (1) engagements focus on business strategy, financial strategy, climate change, board structure, capital efficiency, and disclosure; (2) targeted firms tend to be large-cap companies with lower controlling shareholder ownership and

[1256] https://www.ipe.com/news/pension-fund-returns-could-suffer-with-climate-change-impact/10126581.article; https://www.pensionpolicyinternational.com/how-climate-change-will-impact-pension-fund-investment-portfolios/

[1257] https://www.pensionpolicyinternational.com/pension-funds-urged-to-account-for-climate-risk-in-private-assets/

higher disclosure activity; and (3) engagements yield measurable outcomes: climate-related engagements reduce Scope 2 GHG intensity[1258] and enhance firm valuation (Tobin's Q, price-to-book ratio), while governance-related engagements increase total shareholder returns (TSR), independent board members, and reduce cross-shareholdings. The study concluded: 'These findings underscore the role of universal owners in influencing corporate behavior, demonstrating that structured engagement can drive meaningful change in corporate governance, sustainability, and financial performance'.[1259]

In March 2023, TPT (The Pensions Trust) Retirement Solutions, one of the UK's largest workplace pension plans, announced that it had introduced climate change considerations into its investment decisions. Cliff Speed, TPT's chief investment officer, said: 'Climate change has the potential to reduce the security of our members' retirement benefits and represents a systemic risk to the long-term value of our investment portfolio. At the same time, the investment required to transition to a net-zero economy presents an opportunity to support the expansion of climate solutions. For us, this means taking an approach to managing our investment risks and opportunities on behalf of our members in line with our fiduciary duty'. In 2016, TPT made its first allocation to renewable energy generation and renewable supporting technologies. It also invested in two additional renewable energy strategies in 2021. It is on the global steering group of the Paris Aligned Investment Initiative, a global forum representing investors (known as Paris Aligned Asset Owners (PAAO)[1260]) with $34trn in assets aligning their portfolios and activities to the goals of the Paris Agreement.[1261]

In March 2024, the People's Pension, a £26bn UK multiemployer DC scheme, announced that it had moved £15bn from developed markets equities to a strategy based on the EU's Climate Transition Benchmark (CTB) methodology and would now follow regional MSCI Climate Change Indexes. The methodology involves an immediate 30% reduction in financed emissions, additional portfolio decarbonization by 7% each year, and divestment from companies that produce thermal coal within the assets covered by the new strategy. It said the primary aim was 'to manage the long-term risks posed to members' investments by climate change and a green transition, that aren't currently being priced by the market' which in turn meant 'members can be confident their investments are working toward the goals of the Paris Agreement'.[1262] In April, the People's Pension introduced a new responsible investment policy that required fund managers to have a commitment to net

[1258] Scope 2: indirect emissions created from the production of electricity/energy purchased and used by the organization.
[1259] Government Pension Investment Fund Evaluation Project on the Effects of Engagement, May 2024; https://www.gpif.go.jp/en/investment/20240521_engagement_report_en.pdf
[1260] https://www.parisalignedassetowners.org/
[1261] https://www.ipe.com/news/uk-workplace-pension-scheme-plans-investment-in-climate-solutions/10065832.article
[1262] https://www.ipe.com/news/peoples-pension-shifts-15bn-to-eu-climate-transition-benchmark-strategy/10071987.article

zero and adequate resources committed to stewardship; failure to do so could trigger a review and possible transfer of assets to other managers.[1263]

A 2024 survey of UK pension funds by AlphaReal, a real assets manager, found that a majority (90%) of pension funds planned to increase their allocation to renewable energy in the next year: 28% reported they would increase their allocations to 21% or more of the portfolios they manage, while 39% said they would increase their allocations to between 16% and 20%.[1264]

In August 2023, a study by Columbia University, the World Bank and the Sustainable Finance Institute examined the portfolios of five of the world's largest pension funds: the Japan Government Pension Investment Fund (GPIF, assets of $1.5trn), the Norway Government Pension Fund Global (GPFG, $1.4trn), the Netherlands' Stichting Pensioenfonds (ABP, the Dutch civil service pension scheme), $465bn), the Canada Pension Plan Investment Board (CPPIB, $420bn), and the New York State Common Retirement Fund (NYSCRF, $242bn). All invest in renewable energy and all assess the environmental sensitivity of any new investments. GPIF, the world's largest public pension fund, is reducing its holdings of carbon-based companies, invests in two low-carbon-oriented stock indexes, and issues green bonds to raise capital to invest in renewable energy and low-carbon companies. GPFG's revenues come from North Sea oil and gas wells, but it has divested from companies that do not meet its climate or ethical standards. ABP planned to reduce its portfolio's carbon footprint by 40% by 2025. CPPIB is heavily invested in real estate and infrastructure (which includes the ownership of 295 'green-certified' buildings in 25 countries) and has issued $109bn in euro-denominated green bonds. NYSCRF has divested from investments in shale oil and gas and has pledged to have a net-zero portfolio by 2040 by investing in its own low-carbon index. With the exceptions of ABP and GPIF, the report noted that the other funds 'fail to define their objectives in numeric terms'.[1265]

In December 2023, the California Public Employees' Retirement System (CalPERS), the largest US public pension fund, announced plans to invest $100bn in climate solutions by 2030 (the CalPERS Sustainable Investments 2030 strategy), as part of its aim of cutting emissions from its portfolio investments to net zero by 2050, while securing long-term financial returns for its members. CalPERS said it wanted to address the major risks that financial markets and companies face as a result of the changing climate, such as business interruptions and damage to assets as a result of hurricanes or flooding It also wanted to participate in the 'booming new clean economy, creating new markets, and investing in the next batch of winners as this shift continues to accelerate exponentially – and avoiding being left behind with dwindling markets, outmoded business models, and stranded assets'. According to the International Energy Agency, a record $1.8trn was invested in clean

[1263] https://www.pensionpolicyinternational.com/uk-peoples-pension-ramps-up-esg-expectations-of-asset-managers
[1264] https://www.pensionpolicyinternational.com/uk-pension-funds-turn-to-renewable-energy-investment/
[1265] https://www.pensionpolicyinternational.com/how-5-of-the-worlds-largest-pensions-funds-invest-to-combat-climate-change/

energy in 2023, more than was invested in fossil fuel energy.[1266] In January 2025, CalPERS, with $502.9 billion in assets, revealed that it was more than halfway towards its $100bn goal, with around $53bn committed to climate adaptation, transition, and mitigation efforts.[1267] In March 2025, CalPERS called for a shift in climate disclosure narratives, emphasizing that companies need to highlight opportunities alongside risks. It noted that the past decade has focused heavily on risk disclosure, and companies should be more vocal about their positive climate initiatives, particularly in areas such as green revenues.[1268] In December 2025, CalPERS announced that it had invested $5bn in a customized public equity Climate Transition Index that tilts towards companies that have a transition plan and reduces exposure to those that do not. Companies' weighting in the index is determined by the amount of green revenue they generate. High emitters are included in the index if they also have renewable energy assets or use carbon capture technology, for example.[1269]

However, a survey of 24 US public pension funds conducted for a report called *The Hidden Risk in State Pensions: Analyzing State Pensions' Responses to the Climate Crisis in Proxy Voting* found that 'too few state pensions are taking adequate steps to address climate-related financial risks and protect their members' hard-earned savings, raising serious concerns about their execution of fiduciary duty'.[1270] On the other hand, a study by Kahn et al. (2024) found that ownership and active constructive engagement from US public pension funds were more effective than confrontational tactics, such as voting or shareholder proposals. In particular, they found that companies reduced their greenhouse gas emissions when stock ownership by 'green' funds (where the majority of trustees were Democrats or were located in states with a Democratic governor) increased, and did not alter their emissions when ownership by 'non-green' funds (e.g., those in Florida or Texas) changed. The authors concluded that widespread disinvestment from companies currently in the fossil fuel business could be misguided and lead to unintended consequences.[1271]

In December 2023, the Dutch pension fund Pensioenfonds Metaal & Techniek (PMT) announced it had divested from 40 oil and gas companies, but remained invested in nine European companies (Shell, Aker BP ASA, BP, Enbridge, Eni, Equinor, Galp Energia, Neste and OMV) with 'sufficiently convincing plans' for the energy transition and carbon reduction. The 40 companies sold did not have sufficiently ambitious and substantiated $CO_2$ reduction targets to commit to the Paris Agreement goals. Although the retained companies were not currently operating in line with the goals – which applies to

[1266] https://www.pensionpolicyinternational.com/the-largest-u-s-pension-fund-just-rolled-out-a-climate-transition-plan-focused-on-risk-and-opportunity/
[1267] https://www.top1000funds.com/2025/01/calpers-goes-big-on-the-green-transition
[1268] pionline, 12 March 2025
[1269] https://www.top1000funds.com/2025/12/calpers-bets-on-outperformance-from-growing-climate-allocation
[1270] https://www.pensionpolicyinternational.com/us-too-few-public-pension-funds-address-climate-in-proxy-voting-report/
[1271] Matthew E. Kahn, John G. Matsusaka and Chong Shu (2024) Measuring the unintended consequences of public pension fund disinvestment from fossil fuel companies, CEPR, 26 January; https://cepr.org/voxeu/columns/measuring-unintended-consequences-public-pension-fund-disinvestment-fossil-fuel

the entire global economy – they made progress during the two-year engagement program with the fund and will be continuously monitored to confirm sufficient progress. PMT insists the companies must stop developing new oil fields by 2025, but can continue to develop new gas fields due to the global scarcity of natural gas. PMT's strategy is to keep talking to polluters and 'not simply exclude companies or a sector'. This contrast with two other large Dutch pension funds, ABP and PME, which have divested from the entire fossil sector.[1272]

In March 2024, ABP announced that it would invest a total of €30bn in energy transition and non-listed impact investments targeted at biodiversity solutions, innovation and affordable housing. It said that it had identified climate and biodiversity 'as the key themes influencing societal and economic changes, presenting risks and opportunities in the investment portfolio'. It also said that it would stop investing in companies 'where climate or biodiversity damage is inherently linked to their business activities, with no realistic prospect of improvement' which potentially included companies involved in the meat, cacao, coffee, palm oil, animal feed or paper and wood industries.[1273]

In February 2025, PGGM,[1274] the investment manager that invests on behalf of five Dutch pension funds (in particular, the healthcare pension scheme PFWZ), announced it had taken a 49% stake in Carbon Collectors, a Dutch company involved in carbon capture. This was part of a €1bn investment that will be allocated to climate-related start-ups.[1275]

In March 2025, the £78bn Universities Superannuation Scheme (USS), the UK's largest pension fund, announced that was going to spend more time on engagement with government and corporates than producing emissions reports. Between 2019 and 2023, it reduced the carbon emissions of its asset portfolio by 35%. It did this by tilting to climate-friendly assets, reducing its exposure to companies poorly positioned to adapt, and investing directly in renewables. Despite this, global emissions have continued to increase. USS argues that the carbon reporting burden was distracting from more useful strategies like engagement to encourage others to act as long-term players. It added that policy change was a precursor to meaningful corporate change and it wanted to help create a landscape and economic framework within which corporates and consumers can choose lower carbon options.[1276]

In March 2025, a survey by consultant XPS of 48 pension schemes' task force on climate-related financial disclosure (TCFD) reports found that 75% of schemes had adopted net-zero targets in 2024, an increase from 60% in 2023. In addition, 69% had made asset

[1272] https://www.pensionpolicyinternational.com/dutch-pension-fund-pmt-sells-most-fossil-fuel-holdings/
[1273] https://www.ipe.com/news/abp-pledges-30bn-for-new-impact-investments/10071989.article
[1274] https://www.pggm.nl/en/about-us/about-pggm/
[1275] https://impact-investor.com/pggm-buys-stake-in-dutch-carbon-capture-company/
[1276] https://www.top1000funds.com/2025/03/uss-calls-time-on-emissions-reporting

allocation changes to address climate risks, while 42% had some direct investment in climate solutions. In total, the schemes surveyed had £400bn in assets.[1277]

In April 2025, Local Pensions Partnership Investments (LPPI), the £27bn investment pool for three funds in the UK Local Government Pension Scheme – Lancashire County Pension Fund, the London Pensions Fund Authority and the Royal County of Berkshire Pension Fund – launched a £500m LPPI Environmental Opportunities Fund, a private markets fund focused on decarbonisation investment opportunities, in particular, climate mitigation, climate adaptation, and the protection, restoration, and sustainable management of nature.[1278]

In April 2025, Border to Coast Pensions Partnership agreed to invest £40m in a UK life science fund managed by UBS Asset Management's Real Estate & Private Markets and £40m in a renewables impact fund managed by Quinbrook Infrastructure Partners (the Quinbrook Renewables Impact Fund (QRIF) II fund). The former fund has assets in the 'golden triangle' region encompassing Cambridge, Oxford and London. The latter fund will invest in projects, such as the 2,000-acre Mallard Pass solar farm on the Rutland/Lincolnshire border, which will generate sufficient energy to power 92,000 UK homes, and battery storage facilities aimed at decarbonising commercial vehicles.[1279]

In April 2025, Pensioenfonds ING, the pension fund of Dutch bank ING, appointed Achmea Investment Management as a strategic advisor for impact investing, with an emphasis on investments in climate, health and nature themes in private markets. This aligns with a call from the Netherlands Advisory Board on impact investing for the country's pension funds, asset managers, insurance companies and banks to allocate at least 10% of their assets under management to impact investments by 2025.[1280]

In May 2025, the Canada Pension Plan, Canada's largest pension fund, revealed in its annual report that it had dropped its net-zero commitments: 'forcing alignment with rigid milestones could lead to investment decisions that are misaligned with our investment strategy. To avoid that risk – and to remain focused on delivering results, not managing legal uncertainty – we have made a considered decision to no longer maintain a net zero by 2050 commitment', a promise first made in 2022. It said that this was partly in response to the anti-greenwashing rules contained in Canada's Competition Act which requires entities to prove the environmental claims they make: 'Recent legal developments in Canada have introduced new considerations around how net-zero commitments are interpreted. In particular, there is increasing pressure to adopt standardized emissions metrics and interim targets, many of which don't reflect the complexity of a global

[1277] https://www.pensionpolicyinternational.com/uk-three-quarters-of-pension-schemes-have-now-adopted-net-zero-targets/; https://xps-13503-s3.s3.eu-west-2.amazonaws.com/files/1717/4306/7339/XPS_Group_TCFD_in_Review_Year_3_002.pdf
[1278] https://www.ipe.com/news/local-pensions-partnership-launches-climate-solutions-fund/10129778.article
[1279] https://realassets.ipe.com/news/border-to-coast-invests-80m-in-uk-life-science-real-estate-and-renewables/10129920.article
[1280] https://impact-investor.com/achmea-im-to-advise-ings-pension-fund-on-impact-investing

investment portfolio like ours'. However, John Graham, CEO of the Canada Pension Plan Investment Board, added: 'Nothing's changed on what we're actually doing. We think it is really important to incorporate climate and incorporate sustainability into the portfolio when we take a long-term perspective and as a long-horizon investor'.[1281]

In November 2025, CalPERS announced that it had $60bn in climate solution investments, with a target to reach $100bn by 2030. It said 'our real focus is on returns and we believe by targeting this segment, we can generate outperformance'. It highlighted global opportunities in renewable energy across emerging markets like India and Vietnam, as well as developed economies like Japan which has a $1trn Green Transformation strategy.[1282]

### Smaller pension schemes

In August 2024, a study by The Pensions Regulator in the UK of 3,500 schemes found that many smaller schemes only had minimum compliance with ESG aspects of statements of investment principles (SIPs) and implementation statements (ISs). Trustees often failed to demonstrate ownership of their policies or key activities in respect of ESG and where they delegated activities to managers, they often failed to explain or demonstrate oversight of ESG activities. Further, where schemes are invested in pooled funds, a number of trustees highlighted they had limited ability to influence underlying managers on decisions related to ESG. TPR said scheme trustees should aim to fully demonstrate their engagement with material ESG considerations whether climate impact, nature loss or social factors and invite challenge in the interest of protecting outcomes for savers.[1283] In the same month, a study by Climate Safe Pensions found that, with $46trn in assets worldwide, pension funds were still amongst the largest institutional investors in fossil fuels, holding nearly 30% of fossil fuel industry shares.[1284]

In March 2025, Scottish Widows *Responsibly Invested Pensions* survey revealed that 69% of employers in the UK offered a responsibly invested company pension, but only 44% have it as their default fund option for their DC scheme. This put the burden on employees to take action if they want to switch; however 61% of employees reported that had 'no idea' how to change their default, highlighting a need for employers and advisers to educate workers on this issue. The survey also found that more employees have become interested in how environmental, social and governance 'friendly' their company pension scheme is: 17% employees class their pension's environmental or social impact as a top priority, rising to 25% for those aged 18-34. The survey said employers were taking a range of approaches to embedding responsible investment into their pensions: 53% were allocating pensions to

[1281] https://www.ipe.com/news/canadas-largest-pension-fund-drops-net-zero-promise/10130676.article
[1282] P&I Daily, pionline@e.crainalerts.com, 10 November 2025
[1283] https://www.ipe.com/news/tpr-report-missed-opportunity-as-trustees-focus-on-minimum-esg-compliance/10074997.article
[1284] https://www.pensionpolicyinternational.com/pension-funds-should-protect-our-future-not-destroy-it/

specific sustainable funds, 46% were invested in impact strategies, and 45% were focused on investing in companies cutting carbon emissions.[1285]

## Recent developments

In December 2025, the Climate Policy Initiative published *State of OECD Pension Funds' Climate Transition*.[1286] The report examined the progress for the climate transition of 594 pension funds based in OECD countries, representing $22.5 trillion in assets. It measured the funds' progress across the three dimensions of Targets, Implementation, and Impact to identify where pension funds are making meaningful progress and where further action is needed. To do this, it used data from the CPI's Net Zero Finance Tracker (NZFT).[1287] Table 1 summarizes the overall improvement of OECD-based pension funds across the NZFT dimensions over 2020-24.

The key findings of the report are:

- Pension funds are ramping up their climate Targets and Implementation. Climate is becoming a core element of their long-term investment strategy.
- Pension funds have a significant influence on the decarbonization of the real economy, but remain materially exposed to fossil fuels. Pension funds' investments are misaligned with the net-zero scenarios of the International Energy Agency and the Network for Greening the Financial System (NGFS).
- Once pension funds integrate climate into their targets and strategies, they match or surpass other financial institutions' ambition and action. Pension funds generally outperform other entities by setting more ambitious fossil fuel exclusion phase out targets, using policy engagement to drive legislative change, and implementing more robust climate risk strategies.
- Target-setting, Implementation measures, and transition plans matter. They correspond to measurable shifts in portfolio allocation and in how pension funds think about climate. The adoption of targets, implementation measures and transition plans correlates with a higher share of holdings in clean energy for the sampled funds.
- Strong, well-designed policies are crucial to embed climate considerations in pension funds' strategies. When fiduciary duty explicitly includes climate and climate-related disclosures are mandatory, pension funds tend to set stronger targets and implement them more fully.
- The asset owner–asset manager relationship is a critical lever for change and is emerging as a central channel through which pension funds influence the climate transition. The largest pension funds are increasingly using mandates and

[1285] https://www.pensionpolicyinternational.com/uk-two-thirds-of-employers-embrace-responsible-pensions-less-than-half-have-it-as-their-default/
[1286] https://www.climatepolicyinitiative.org/wp-content/uploads/1996/12/State-of-OECD-Pension-Funds.pdf
[1287] https://netzerofinancetracker.climatepolicyinitiative.org/

incentives to drive climate alignment across their external managers and to scrutinize their relationships more closely.

**Table 1: OECD pension funds' progress, performance, and comparison to other OECD institutions, 2020-24**

| | Indicator scores | Improvement (2020-24)[1] | Current Performance (2024)[2] | Quality of adoption vs other OECD entities in the NZFT (2024)[3] |
|---|---|---|---|---|
| Targets | Mitigation target | Very strong | Strong □□□ | Similar |
| | Climate investment target | Medium | Very weak □□□ | Similar |
| | Fossil fuel phase-out and exclusion targets | Medium | Weak ■□□ | Stronger |
| Implementation | Internal accountability framework | Very strong | Strong ■□□ | Weaker |
| | Shareholder and client engagement | Medium | Strong □□□ | Similar |
| | Policy engagement | Medium | Medium ■□□ | Much stronger |
| | Climate risk strategy | Strong | Strong ■■■ | Similar |
| | Climate risk management | Very strong | Strong ■■■ | Stronger |
| | Disclosure of climate risk | Medium | Medium □□□ | Similar |
| | Disclosure of investment data | Medium | Weak ■■□ | Weaker |
| | Disclosure of emissions data | Medium | Medium □□□ | Much stronger |
| | Net zero without offsets | Very weak | Very weak □□□ | Much weaker |
| Impact | Energy exposure (% clean energy) | | Weak | Much stronger |
| | Indirect financing (% clean energy) | | Strong | Similar |

Notes:

1 **Improvement** shows the change from 2020–24 in share of AUM/O scoring beyond *No action/Planned.*
Percentage point increase: <20% very weak; 20–30% weak; 30–40% medium; 40–50% strong; >50% very strong.

2 **Current performance** relates to the share of AUM/O in 2024 scoring beyond *No action/Planned.*
<40% very weak; 40–50% weak; 50–60% medium; 60–70% strong; >70% very strong.
For the impact indicators: <20% very weak; 20–40% weak; 40–60% medium; 60–80% strong; >80% very strong.
For targets & implementation, the square symbol indicates the share of Advanced/Best Practice:
□□□ <10% ■□□ 10-20% ■■□ 20-30% ■■■ >30%

3 **Quality of adoption** compares the percentage point difference of the share of AUM scoring *Advanced/Best Practice* of the pension fund sample with other entity types across the rest of the NZFT.
Gap in percentage points: <5% similar; 5–10% stronger/weaker; >10% much stronger/weaker.

The report concludes that:

*credible targets, robust implementation frameworks, and well-designed transition plans are associated with higher allocations to clean energy and more systematic management of climate risk. Where policy frameworks provide clear expectations on fiduciary duty,*

*climate risk management, and disclosure, pension funds go further and faster. Where regulation is fragmented or permissive, progress is slower and more piecemeal, despite growing climate risks and the scale of finance required.*

*Unlocking the potential of pension funds will therefore require a more supportive operating environment. Policymakers must move from ambiguity to clarity on climate-related duties, align disclosure and taxonomy frameworks, and remove barriers to climate-aligned investment. Pension funds, in turn, need to deepen their own targets, data, governance, and policy engagement, while using their leverage over asset managers through mandates, incentives, and stewardship expectations. Asset managers must respond with investment processes and products that are genuinely consistent with their clients' net-zero objectives.*

## UN-supported initiatives relating to asset owners, asset managers, insurers and banks

We now consider some UN-supported initiatives relating to asset owners, asset managers, insurers and banks.

### Principles for Responsible Investment

One of the earliest, established in 2005, was the Principles for Responsible Investment (UNPRI or PRI),[1288] an international network of financial institutions whose aim is to implement six 'Principles':

- Principle 1: We will incorporate ESG issues into investment analysis and decision-making processes.
- Principle 2: We will be active owners and incorporate ESG issues into our ownership policies and practices.
- Principle 3: We will seek appropriate disclosure on ESG issues by the entities in which we invest.
- Principle 4: We will promote acceptance and implementation of the Principles within the investment industry.
- Principle 5: We will work together to enhance our effectiveness in implementing the Principles.
- Principle 6: We will each report on our activities and progress towards implementing the Principles.

In April 2024, UNPRI issued ten priorities for embedding sustainability in pension systems:[1289]

[1288] https://www.unpri.org/

[1289] Progress and priorities: reviewing sustainability in key pension systems; https://www.unpri.org/private-retirement-systems-and-sustainability/progress-and-priorities-reviewing-sustainability-in-key-pension-systems/12285.article

1. The policy framework is comprehensive and consistent

   Policy makers develop a comprehensive, consistent and supportive policy framework that provides clarity for pension funds as they seek to address sustainability risks and opportunities, including system-level risks, when they pose a threat to achieving their financial objectives. Policy and regulatory frameworks ensure that:

   (i) There is clarity regarding the duties and obligations of pension funds to incorporate ESG factors into investment decisions and stewardship activity, and to consider taking action to pursue sustainability outcomes that are instrumental to fulfilling financial objectives in line with members' and beneficiaries' preferences.
   (ii) The long-term investment horizon and fiduciary duties of pension funds are recognized, incentivized and protected through appropriate parameters in investment decision-making, product choice and the tenure of pension fund trustees and senior executives, leading to decision-making that prioritises long-term goals.

2. Policy and regulation distinguish between addressing exposure to sustainability-related risks, tackling underlying drivers of such risks and pursuing sustainability outcomes in parallel with financial objectives

   Pension funds are enabled to move beyond ESG integration at a risk-return level and pursue sustainability outcomes. Standards and guidance should clarify when pension funds may be required to consider addressing system-level risks relevant to financial objectives, as well as when and how they might pursue sustainability objectives in the best interest of members and beneficiaries.

3. Pension funds, investment managers and intermediaries produce standardized reporting on sustainability objectives

   Standardized reporting provides information about the extent to which pension funds have met stated sustainability objectives and taken action to achieve those objectives. Similarly, investment managers and relevant intermediaries in the investment value chain align their reporting to support pension funds. Reporting by pension funds is in a format that is accessible to members and beneficiaries.

4. There is appropriate guidance on the sustainability claims of pension funds

   Regulators provide guidance to pension funds on how to demonstrate the sustainability claims of their offerings and ensure that their disclosures indicate the types of strategies that facilitate these claims. This is a key factor in ensuring that members and beneficiaries have confidence in the sustainability characteristics of their products. Such guidance should not create unnecessary restrictions on the

types of strategy that can be considered sustainable, providing adequate incentives to innovate.

Market structure

5. Pension funds have scale or can otherwise access the benefits of scale

   Policy makers and regulators encourage fund consolidation where there are benefits to the market within which the funds are operating. However, the impacts of consolidation on sustainability objectives and strategies should be properly considered. In the absence of consolidation, policy makers and regulators encourage pooling of investments or resources, including encouraging sharing of resources on stewardship activities.

6. Suitable, sustainable investment products are available and accessible

   Pension funds can access investment products with their desired sustainability characteristics, at appropriate cost and scale, to achieve their sustainable investment objectives.

Investment practices

7. Members and beneficiaries are educated about and engaged with regarding their sustainability objectives

   Pension fund members and beneficiaries are appropriately educated about and regularly and systematically engaged with regarding their sustainability objectives. Where appropriate, the views of members and beneficiaries are reflected in pension fund sustainability strategies.

8. Trustees and fiduciaries are capable and skilled, with sustainability knowledge

   Trustees and fiduciaries are equipped to meet high professional standards and receive sustainability-related training.

9. Trustees and fiduciaries are willing to move beyond traditional pension fund investment strategies and identify, implement and support the development of appropriate benchmarks to take action to pursue sustainability outcomes in keeping with their fiduciary duties

   This includes provision of adequate incentives and market settings for moving, where appropriate, from traditional benchmarks focused on short-term, portfolio-level risks, towards benchmarks that allow the measurement of a scheme's impact on system-level risks and the impacts of system-level risks on funds over longer time frames.

10. Service providers are adequately incentivized to support the pursuit of pension funds' sustainability objectives

    Service providers (notably investment managers and consultants) are adequately incentivized, able and willing to provide products and services that support pension funds' sustainability objectives. This includes protecting against the adverse impacts of market concentration, such as the potential for conflicts of interest or impacts on the principal-agent relationship due to the size of intermediaries relative to the pension fund clients they serve.

In March 2025, figures from the PRI – based on the reports of more than 3,000 of its signatories which represent nearly $90trn in assets under management – indicated that between 2023 and 2024, there was an increase in the proportion of asset owners, from 14% to 19%, that did not include any responsible investment clauses in their contracts with managers. In addition, fewer asset owners required their managers to adopt their exclusion criteria, incorporate material ESG factors into investment and stewardship activities, or report on their responsible actions over the period. More than 50% of respondents are based in Europe, 23% in North America and 10% in Asia.[1290]

In December 2025, the PRI announced that, in 2026, it will reduce signatories' responsibilities in their annual mandatory reporting, by reducing the number of questions asked from 240 to 40. It said: 'The reporting system has been very important, and it's been such a critical element of the growth of responsible investment around the world, but at a time when there are now so many other mandatory requirements and voluntary codes, our signatories were drowning under the amount of work they had to do. … [Nevertheless], the simplified assessment will be just as rigorous'.[1291]

### Net-Zero Asset Owner Alliance

The UN-convened Net-Zero Asset Owner Alliance (NZAOA)[1292] was established in 2019 by Allianz, Caisse des Dépôts, La Caisse de dépôt et placement du Québec (CDPQ), Folksam Group, PensionDanmark and Swiss Re – with Alecta, AMF, CalPERS, Nordea Life and Pension, Storebrand, and Zurich Insurance joining shortly after. Members commit to transitioning investment portfolios to net-zero greenhouse gas emissions by 2050. In May 2021, four UK pension asset owners joined the Alliance – Phoenix Group, L&G, Rothesay and Prudential (UK) – bringing the total membership to 42 and combined assets of $6.6trn.[1293] By October 2023, assets had grown to $9.5trn[1294] and there were 88

[1290] https://www.ipe.com/news/drop-in-asset-owners-including-responsible-investment-clauses-manager-contracts/10129674.article
[1291] https://www.top1000funds.com/2025/12/pri-slashes-reporting-burden-to-preserve-code-relevance-among-signatories/
[1292] https://www.unepfi.org/net-zero-alliance/
[1293] https://www.pensionpolicyinternational.com/uk-pension-asset-owners-join-net-zero-asset-owner-alliance/
[1294] *Insurance Asset Management*, 19 October 2023.

members, of which around 60 were European pension funds and insurers, with new joiners such as Danica Pension, the BT Pension Scheme and AXA.

In November 2023, NZAOA published its engagement expectations for investment managers wanting to win and retain mandates from its members: 'asset managers must adopt a consistent, transparent, and outcomes-oriented climate engagement strategy, which recognises that climate change poses systemic risks to asset owner portfolio returns. [Such an approach would be] critical for asset managers' continued ability to win mandates of clients committed to net zero'. Managers were recommended to get climate engagement processes and standards verified or assured. In addition, asset managers would be expected to explain their approach, objectives and deadlines for securing real-world change for each engagement they undertake, as well as 'transparently share their expectations of issuers and, importantly, their successes and learnings from engagement'.[1295] In February 2024, NZAOA launched a call for action by investment managers by sending a clear message that serving asset owner clients was only possible through climate stewardship. Investment managers needed to ensure their net-zero pledges were being taken up by senior leadership or they would start losing out on mandates.[1296]

In April 2024, NZAOA released the fourth edition of the Target-Setting Protocol, covering all private assets, requiring the halving emissions by 2030 and ensuring 20% of AUM are in green investments by 2030.[1297] In September 2024, NZAOA announced that that there had been a 6% annual reduction in greenhouse gas emissions registered by its 88 members (90% of which are either insurers (62%) or pension funds (28%)) since 2018 which meant that the group was on target for achieving net zero emissions by 2050. Eighty members have set targets for investments in 'climate solutions' which contribute to real-world decarbonization.[1298] Mark Lyon, deputy CIO of the UK's Border to Coast pension pool, explains how this annual reduction is being achieved: '[It requires some annual rebalancing of the portfolio]. Many of the new managers we're choosing tend not to invest in high-emitting, old-economy stocks like energy and materials because they're more focused on growth. The rest has been achieved by the companies themselves. We own more than 1,000 companies, and the top 60 or 70 account for more than half our emissions. So, if we get those companies to transition, we can see big changes almost immediately. And that's what's happened'. Ravien Sewtahal, senior investment manager at the Dutch pension fund PFZW, said 'some of the decarbonisation has come from the scheme's decision to sell almost all its oil and gas stocks, which it believes will reduce financial risks over the longer term. The board has an intrinsic motivation to change things in the real world because we know it will be much easier to make returns for our participants if the planet is not on fire or under water. …[PFZW] recently launched a strategy to make direct investments into

[1295] https://www.ipe.com/news/net-zero-engagement-asset-owners-publish-rules-for-managers/10070072.article
[1296] https://www.ipe.com/news/asset-owners-warn-managers-to-take-climate-pledges-seriously/10071464.article
[1297] *Insurance Asset Management*, 18 April 2024.
[1298] https://www.pensionpolicyinternational.com/net-zero-asset-owner-alliance-unveils-milestone-emissions-cuts/; https://www.ipe.com/news/net-zero-asset-owners-have-successfully-decarbonised-in-line-with-15c/10076517.article

European companies providing solutions to the climate crisis and supporting the transition to a low-carbon economy through things like new heating and cooling systems. That was a really big step in telling our participants that we're contributing to real-world change not just by encouraging big companies to decarbonise, but by financing good investment ideas that will help make it possible. …Now we have the flexibility to invest in more climate solutions, as long as they create real-world impact, stay close to our overall investment beliefs and fit within our risk management constraints. The new model also creates synergies and awareness within our broader organization around climate transition investing'.[1299]

Also in September 2024, the London Stock Exchange Group (LSEG) published a Decarbonization in Portfolio Benchmarks report in association with NZAOA. It found that between 2016 and 2022, the weighted average carbon intensity of the FTSE All-World equity index had declined by 4.1% annually on a revenue basis (Weighted Average Carbon Intensity (WACI)) and 5.1% on an ownership basis (Enterprise Value Including Cash (EVIC), the sum of market capitalization plus total debt). Similar rates occurred in corporate fixed income, with the FTSE WorldBIG Corp index decarbonizing at 3.9% (WACI) or 1.4% (EVIC) p.a. over the same period. At a benchmark level, 90% of the equity benchmark by index weight and 85% of the corporate fixed income universe now disclose their Scope 1 and 2. Scope 3 disclosure remains more limited due to poor data quality.[1300]

In January 2025, NZAOA requested information about asset managers' carbon dioxide removal investments. It said that phasing in investments in carbon removal solutions, both nature-based and technology-based, 'cannot wait', particularly 'if decarbonisation falters': 'That is why the Alliance is publishing this request for information, seeking to contribute to capacity building and knowledge sharing, and ultimately investment scaling in this space', while recognizing there were limitations to carbon dioxide removal solutions with commercial viability and uncertainty about long-term demand.[1301]

In October 2025, NZAOA called on governments to change the regulation of the market for Carbon Dioxide Removals (CDR) to make it easier for its members to invest in the market in order to achieve their long-term climate commitments. NZAO bans members from using carbon removals to achieve portfolio decarbonisation targets before 2030, requiring them instead to focus on reducing the emissions of their underlying portfolio companies. However, members will be able to use the CDR market to meet their post-2030 net-zero targets, allowing them to 'net out' residual portfolio emissions. NZAOA wanted global governments to pursue 'CDR positive policies', including adding carbon removals in regulated markets. It also wanted governments to add CDR targets into their official climate commitments under the Paris Agreement. Further, it called for the adoption of shared definitions and standards, along with a robust certification process for CDR

[1299] https://www.ipe.com/special-reports/pension-funds-outline-progress-towards-net-zero/10076568.article
[1300] https://www.lseg.com/content/dam/lseg/en_us/documents/sustainability/lseg-decarbonisation-portfolio-benchmarks-report.pdf
[1301] https://www.ipe.com/news/net-zero-asset-owner-body-issues-carbon-dioxide-removal-info-request/10128439.article

credits, more global trading infrastructure, and insurance options to make projects more bankable.[1302]

In November 2025, NZAOA reported that members channelled 8% ($743bn) of their total assets under management into climate solutions, of which 30% was done via listed equity portfolios, 26% via corporate bonds and only 7% via private assets. Members had achieved 78% of their targets for engagement with portfolio companies, asset managers, sectors and value chains. NZAOA said it would expand into private markets in the initiative's next phase. It also planned to phase in decarbonisation targets for private markets under its target-setting protocol.[1303]

### Net Zero Asset Managers initiative

The Net Zero Asset Managers initiative (NZAM) was launched in December 2020 – as a formal partner of the UN's Race to Zero Campaign[1304] – and aims to galvanize the asset management industry to commit to a goal of net zero emissions.[1305] At the time of COP26, NZAM announced that 35% of their assets under management were being managed in line with net-zero emission targets.[1306] Morningstar reported that in 2021 there were 860 mutual funds and exchange-traded funds (ETFs) with a climate-focused mandate with total assets of $408bn, double the previous year.[1307] Climate Impact Consistent (CIC) Indices have been introduced for net-zero investors. They weight each company in proportion to its net-zero alignment, as measured through its carbon emissions intensity, its emissions disclosure/quality, its forward-looking emissions targets and their credibility, and its revenues from climate solutions.[1308] By mid-2024, NZAM had around 325 members with $57.5trn in assets under management.[1309]

At the COP26 meeting, BlackRock, then a NZAM member, announced that it had raised $673m in public and private sector money for a new infrastructure fund which would invest in climate-related projects in emerging markets.[1310] The International Energy Agency estimates that investment in energy transition in emerging markets needs to rise to $1trn a year by 2030 if the world is to reach the net-zero target by 2050.[1311] In 2023, British International Investment (BII), the UK's development finance institution, signed an agreement with ILX, an Amsterdam-based manager of an emerging market private debt fund, to co-finance up to $500m of debt to support long-term sustainable development in

[1302] https://www.ipe.com/news/asset-owners-urge-policymakers-to-regulate-carbon-removals-market/10133473.article
[1303] https://www.ipe.com/news/asset-owners-to-step-up-net-zero-engagement-with-private-markets/10133766.article
[1304] https://unfccc.int/climate-action/race-to-zero-campaign
[1305] https://www.netzeroassetmanagers.org/
[1306] https://www.ipe.com/news/average-35-of-assets-initially-in-scope-for-net-zero-manager-targets/10056078.article
[1307] https://www.investmentweek.co.uk/news/4048291/assets-climate-focused-funds-soar-usd408bn-2021
[1308] *IPE*, 17 May 2021.
[1309] *Insurance Asset Management*, 24 July 2024.
[1310] *Financial News*, 7 March 2022.
[1311] *Financial News*, 7 March 2022.

developing and low-income countries in Africa, Asia, and the Caribbean, through investing in sectors, such as renewable energy, infrastructure, financial services, manufacturing and agribusiness.[1312] In 2023, there were around 400 private debt impact funds and more than two-thirds were lending to emerging markets. Although the total was only 3% of private credit globally, there was growing recognition of the potential for financial returns that create positive social and environmental outcomes, according to Vincent Lemaitre, head of ESG for private debt at Tikehau Capital.[1313]

However, in December 2022, Vanguard, the world's second largest fund manager and the world's largest manager of index funds, announced: 'After a considerable period of review, we have decided to withdraw from NZAM so that we can provide the clarity our investors desire about the role of index funds and about how we think about material risks, including climate-related risks – and to make clear that Vanguard speaks independently on matters of importance to our investors. [The move] will not affect our commitment to helping our investors navigate the risks that climate change can pose to their long-term returns'.[1314] The move followed pressure from some investors and Republican politicians in the US to decrease reliance on ESG criteria when making investments, on the grounds that this negatively impacts the ability of companies such as Vanguard to maximise returns for shareholders, requires disinvestment from fossil fuel at a time when energy security is paramount, and violates anti-trust rules. Index funds face a particular issue since they, by definition, invest in all securities in proportion to their market value and do not discriminate on the basis of the economic activities of the companies issuing those securities. Further, there are no commonly agreed sustainable investment benchmark indices in which index funds could invest. As a result, Vanguard has committed less than 5% of its assets under management with net-zero goals.[1315]

Larry Fink, the CEO of BlackRock, the world's largest fund manager, said he has stopped using the term ESG because it had become too politicized and 'entirely weaponized… by the far Left and by the far Right'. Former DWS[1316] Group Sustainability Officer Desiree Fixler has said: 'Beyond politics, there are plenty of other factors fuelling the anti-ESG movement. Lacklustre fund performance, too much red tape and greenwashing have left a sour taste. There's been pervasive greenwashing in the market, and people are fed up with having to pay more for green products which it turns out aren't very green'.[1317] In 2022, Texas blocked state entities, such as pension funds, from investing with BlackRock on account of its 'boycotting' of the oil and gas sector; in 2021, BlackRock had reduced its exposure to oil and gas stocks by around 15% to $552bn. However, BlackRock said it continued to invest in fossil fuels and promised to invest even more in Texas: in February 2024, it announced a $10bn private investment in Texas' power grid, enabling the

[1312] Lauren Mills (2024) Bridging the SDG funding gap with private debt impact funds, *Impact Investor Guide 2024.*
[1313] https://impact-investor.com/bridging-the-sdg-funding-gap-with-private-debt-impact-funds
[1314] https://www.investmentweek.co.uk/news/4061376/vanguard-quits-net-zero-asset-managers-initiative
[1315] https://impact-investor.com/vanguard-exit-unlikely-to-trigger-mass-defections-from-net-zero-initiative/
[1316] DWS is a fund manager which is 80% owned by Deutsche Bank.
[1317] https://www.fnlondon.com/articles/its-time-to-dismantle-this-circus-esg-has-served-its-purpose-say-blackrocks-tariq-fancy-and-dwss-desiree-fixler-20230821

construction of new power plants, including natural gas plants.[1318] Despite this, in March, the Texas Permanent School Fund announced that it would divest $8.5bn from BlackRock over what that State Board of Education's chairman termed BlackRock's ESG-oriented commitment to harm Texas' oil and gas industry.[1319]

In January 2024, the responsible investment campaign group Share Action[1320] accused larger asset management companies of failing to vote on environmental resolutions. Its research showed that on environmental resolutions assessed, only 3% passed in 2023 compared with 32% in 2021; on social resolutions, majority support fell from 15% to 4%. Voting behaviour was also different in different jurisdictions. European asset managers supported 88% of shareholder proposals on environmental and social issues, while support in the UK and US averaged 64% and 25%, respectively. In terms of the so-called 'big four' asset managers, Blackrock, Fidelity, Vanguard and State Street, their average support for environmental resolutions fell from 39% to 14% between 2021 and 2023, while their support for social resolutions fell from 29% to 13%. Blackrock, supported only 8% of resolutions. Share Action also said that asset managers which have signed up to Climate Action 100+[1321] with a mandate to protect the environment 'are at the same time voting down resolutions at AGMs that would improve environmental protections in what can only be described as greenwashing'.[1322] There was also evidence of a growing backlash to ESG investing amongst investors. According to data from Morningstar, sustainable funds in Europe collected $76bn in new money in 2023, about half the sum of $149bn they collected in 2022. ESG bond funds collected 36% more in management fees during 2023, generating $216.8m for fund groups, compared with a 380% increase in fee income for 2022. ESG equity funds experienced an increase in management fees of 18% in 2023 to just over $1bn, down from 290% in 2022.[1323] In February 2024, JP Morgan Asset Management, PIMCO and State Street Global Advisors (SSGA) left Climate Action 100+, while BlackRock transferred its participation to its international arm. BlackRock said: 'The new Phase 2 approach of CA100+ will require signatories to make an overarching commitment to use client assets to pursue emissions reductions in investee companies through stewardship engagement. In our judgment, making this new commitment across our assets under management would raise legal considerations, particularly in the US'. Phase 2, which began in June 2023, involved 'enhanced investor engagement' and a '[marked shifting of]

[1318] https://www.ai-cio.com/news/blackrocks-fink-strikes-truce-with-texas
[1319] https://www.ai-cio.com/news/truce-is-over-texas-school-fund-to-ax-8-5-billion-in-blackrock-investments
[1320] https://shareaction.org/
[1321] Climate Action 100+ is an investor-led initiative to ensure the world's largest corporate greenhouse gas emitters take appropriate action on climate change in order to mitigate financial risk and to maximize the long-term value of assets. Members of Climate Action 100+ are expected to ask their portfolio companies to 'take action to reduce greenhouse gas emissions across the value chain' and 'implement transition plans to deliver on robust targets'; https://www.climateaction100.org/
[1322] https://www.portfolio-institutional.co.uk/esg-hub/asset-managers-under-fire-for-not-voting-on-esg-resolutions/
[1323] https://www.fnlondon.com/articles/esg-fees-stall-as-managers-battle-sustainable-fund-slowdown-20240201

the focus from corporate climate-related disclosure [Phase 1] to the implementation of climate transition plans'.[1324]

In March 2024, Reclaim Finance released a report which analyzed 430 funds labelled as sustainable by five of the world's largest passive investors: BlackRock, DWS, Legal & General Investment Management, UBS Asset Management and Amundi. It found that 70% of the funds were exposed to companies that continued to expand their fossil fuel production. Collectively, the investors had holdings of $227bn in fossil fuel developers in 2023, with more than 50% of this in their passive funds. Reclaim Finance said it wanted regulators to introduce minimum standardized mandatory criteria for funds making sustainability claims and a ban on passive funds holding fossil fuel firms being marketed as sustainable.[1325]

Also in March 2024, a report by PitchBook entitled *The State of Private Market ESG and Impact Investing in 2024* noted that some asset managers were engaged in 'greenhushing', i.e., retreating from their public ESG commitments. These managers were de-prioritizing some of their ESG and impact investing programs due to concerns about potential backlashes from opponents of green and sustainable investment strategies and because of possible reputational damage in the face of claims of greenwashing. The report also found that there was no evidence that ESG strategies meant lower returns. Further, fundraising was lower in 2023 compared with 2023.[1326] Other asset managers have been accused of 'engagement washing', i.e., not delivering meaningful change due to poor quality engagement or, alternatively, exaggerating the impact of their ESG engagement with the companies in which they invest.[1327]

To counteract the politicization of ESG, Blackrock announced that it was switching from ESG investing to 'transition investing' which supports 'strategies that focus on preparing for, being aligned to, benefitting from and/or contributing to the transition to a low-carbon economy'. Larry Fink said: 'We believe the next 10 years is going to be a lot about infrastructure. There is a high demand for capital to fund the world's transition to clean energy. If we are going to decarbonize the world ... capital and infrastructure is going to be very necessary and supply/demand imbalance creates compelling investment opportunities for our clients'.[1328]

In January 2025, a BlackRock investment stewardship note announced that the fund manager would not use its stewardship and voting power to achieve specific real-economy

[1324] https://www.ipe.com/news/climate-action-100-reacts-to-us-asset-manager-exits/10071828.article
[1325] https://www.fnlondon.com/articles/blackrock-lgim-and-dws-sustainable-passive-funds-exposed-to-fossil-fuels-20240320
[1326] https://www.funds-europe.com/greenhushing-impacting-private-markets-esg-activity; https://www.fnlondon.com/articles/greenhushing-esg-fund-marketing-names-20240325
[1327] *Insurance Asset Management*, 12 April 2024; https://www.impactive.pro/blog/what-is-engagement-washing-and-how-to-avoid-it
[1328] https://www.blackrock.com/sg/en/investment-strategies/sustainable-transition-investing; https://www.portfolio-institutional.co.uk/esg-hub/blackrock-transition-investing-a-primer-on-the-what-the-why-and-the-how-2/; https://raoglobal.org/blog/blackrocks-shift-from-esg-investing-to-transition-a-bold-move-towards-sustainable-transformation

decarbonisation goals: 'its team cannot – and does not try to – direct a company's strategy or its implementation [when it comes to climate change]. It is not our role to engineer a specific decarbonisation outcome in the real economy. [Its duty was solely to] advance our clients' long-term financial interests. …The money we manage is not our own – it belongs to our clients, many of whom make their own asset allocation and portfolio construction decisions'.[1329] In the same month, BlackRock announced its withdrawal from NZAM, saying that its membership 'caused confusion regarding BlackRock's practices and subjected us to legal inquiries from various public officials'.[1330] Shortly after this, NZAM announced it had suspended activities: 'Recent developments in the US and different regulatory and client expectations in investors' respective jurisdictions have led to NZAM launching a review of the initiative to ensure NZAM remains fit for purpose in the new global context'. NZAM signatories will be consulted while the initiative tracks signatory implementation and reporting. In the meantime, NZAM has removed from its web site the list of signatories and commitment statements, which also include signatories' net-zero targets and case studies. At the time, NZAM reported that 325 signatories with $57.5trn in assets under management that had made a commitment to achieving net-zero portfolios by 2050.[1331] In the same month, Northern Trust Asset Management (with $1.6trn under management) announced its withdrawal from NZAM and Climate Action 100+ (of which it was a founding signatory), citing confidence in its ability to independently manage material risks and engage with portfolio companies.[1332] In August 2025, finance officials from 21 US states wrote to 25 asset managers expressing 'deep concern' over their sustainability efforts, and giving them 1 September to 'demonstrate [their] commitment to a fiduciary model grounded in financial integrity [rather than] political advocacy'.[1333]

In April 2025, German prosecutors fined DWS Group €25m for 'negligent infringement' relating to ESG statements made between mid-2020 and January 2023, following a previous $19m SEC penalty. The fund manager's claims of being a 'leader' in ESG and 'ESG is an integral part of our DNA' 'did not correspond to reality', according to the prosecutors. DWS admitted that its past marketing was 'sometimes exuberant, but has subsequently improved internal documentation and control processes. The prosecution was triggered by Desiree Fixler's 2021 allegations of greenwashing. It resulted in significant organizational changes including the resignation of the CEO.[1334]

---

[1329] https://www.ipe.com/news/blackrock-distances-itself-from-real-economy-decarbonisation-efforts/10128091.article

[1330] https://www.ft.com/content/f0fb9841-db1d-442e-a757-1a1327497fb1. In 2024, 11 Republican-led states filed a case against BlackRock, Vanguard and State Street, alleging they had conspired to constrain coal supplies and further a 'destructive, politicised environmental agenda'; https://www.ft.com/content/dc34dffe-c92f-4743-8991-f0ec173d083b

[1331] https://www.ai-cio.com/news/net-zero-asset-managers-initiative-pauses-activities-following-blackrock-exit

[1332] https://www.pionline.com/esg/northern-trust-am-leaves-climate-action-100-and-net-zero-asset-managers-initiative

[1333] https://www.ipe.com/news/net-zero-banking-alliance-plans-to-ditch-members-in-bid-to-shake-off-legal-attacks/10132359.article

[1334] https://www.reuters.com/sustainability/german-asset-manager-dws-fined-25-mln-eur-greenwashing-case-2025-04-02/

In October 2025, NZAM announced a 'new chapter', in which its members will no longer have to set climate targets or commit to align with net zero by 2050. This is in response to the growing number of asset managers facing legal action from US politicians opposed to financial institutions making pledges to support the goals of the Paris Agreement. Members told NZAM to loosen membership requirements or face further member losses. NZAM said it would be more explicit about the need for members to consider their fiduciary duties and deliver 'better investment outcomes'. In future, members will be allowed to pursue their own net zero approaches without any reference to reaching net zero by 2050, thereby reflecting 'diverse jurisdictional realities and accommodate signatories from a wider range of markets'. China and the US are among the major countries that are not targeting net zero by 2050: China is aiming for carbon neutrality by 2060 and the US has withdrawn completely from the Paris Agreement. NZAM said it would resume its activities fully in January 2026 with an updated list of members.[1335] These changes were not sufficient to stop State Street Investment Management withdrawing from NZAM in the same month.[1336]

In January 2026, Royal London Asset Management rejoined NZAM, citing the updated Commitment Statement's allowance for a 'more flexible and globally applicable foundation for climate-aligned investing'.[1337] Also in January 2026, a group of 40 asset owners – including AP2, AP3, Border to Coast Pensions Partnership, ERAFP and FRR, Strathclyde Pension and the University Pension Plan Ontario – released a statement recommending that their asset managers should continue to participate in or join NZAM: 'As owners of capital, we will continue to engage with our asset managers regarding their commitment to the NZAM initiative. The updated Commitment Statement presents an opportunity for asset managers to reaffirm their commitment to supporting investing aligned with the global goal of net zero emissions. This sends an important and public signal to the asset owner community and the wider market on how they are managing climate-related financial risks and opportunities on behalf of their clients'.[1338]

In February 2026, NZAM formally relaunched, with around 250 asset managers supporting the overhauled climate stewardship group, down from around 325 members at its peak in 2024. The revised commitment has been significantly weakened, but continues to recognise the importance of limiting global temperature rises to below 2°C above pre-industrial levels, in line with the Paris Agreement. The new framework allows signatories greater flexibility in how they pursue these ambitions, stating that managers should act 'where consistent with fiduciary duty and, where applicable, client mandates'. Rebecca Mikula-Wright, chair of NZAM's steering committee, said: 'Asset managers participating in NZAM send a strong signal to clients, regulators and other stakeholders that they are forward-looking, transparent investors, committed to managing climate-related financial risks and opportunities'. However, only 12 US asset managers have joined the relaunched initiative, including State Street Investment Management, the world's fourth-largest asset manager, but excluding BlackRock, Vanguard and Fidelity Investments. A 2025 study by

[1335] https://www.ipe.com/news/net-zero-asset-managers-initiative-unveils-new-chapter/10133397.article
[1336] https://www.ft.com/content/4fb50d00-9b64-4dbf-b6d5-07b8deceb582
[1337] https://funds-europe.com/rlam-rejoins-net-zero-group-as-others-deliberate/
[1338] https://www.ipe.com/news/asset-owners-point-asset-managers-towards-continued-nzam-involvement/10134935.article

J.P. Morgan Asset Management found that around two-thirds of the world's 100 largest asset owners are committed to supporting sustainable investment. It estimated that $18 trillion in assets are overseen by asset owners incorporating sustainability and active ownership considerations.[1339]

### Net-Zero Insurance Alliance

The Net-Zero Insurance Alliance (NZIA), also convened by the UN Environment Programme (UNEP), was launched in 2021 and has developed the foundational concepts and frameworks to support its members as they work towards decarbonizing their insurance and reinsurance underwriting portfolios.[1340] However, in 2023, a number of major insurers pulled out of NZIA, including Munich Re, Zurich, Hannover Re, Swiss Re, SCOR, Allianz, AXA and Lloyd's of London. Political pressure from some US states and the threat of anti-trust claims have persuaded these companies to leave. Prior to leaving, John Neal, CEO of Lloyd's of London, called on NZIA to make its membership rules less prescriptive or risk falling apart. AXA said it would focus on its own sustainability goals. The remaining members, which include Aviva, Generali and NN, are trying to overhaul NZIA, while remaining 'fully committed to the net-zero transition and [are] engaging with a broader community of stakeholders on the evolution of the NZIA'. A report by Insure our Future found that European insurers, including Lloyd's of London, Zurich and Swiss Re, underwrote more around a third of US coal production. Lloyd's of London is the world's biggest fossil fuel underwriter, earning an between $1.6bn and $2.2bn in annual premiums in 2022. Hortense Bioy, global director of sustainability research at Morningstar, said 'Some insurers have taken steps to align their business with the goals of the Paris Agreement and commit to becoming net zero by 2050, but many haven't. Underwriters face mostly physical risks, and their job is to price and manage these risks. Modelling weather events and physical hazards is their core expertise, and supposedly something they can do better than banks or asset managers. They are already factoring in the fact that as temperatures rise and physical risks increase as a result, more assets will become increasingly difficult, if not impossible, to insure'.[1341]

### Net-Zero Banking Alliance

The Net-Zero Banking Alliance (NZBA) was also launched in 2021 under the UNEP.[1342] Participating banks commit to:

[1339] https://www.netzeroinvestor.net/news-and-views/doubling-down-nzam-relaunch-backed-by-250-managers-but-largest-us-firms-decline-to-join
[1340] https://www.unepfi.org/net-zero-insurance/
[1341] https://www.reinsurancene.ws/axa-and-allianz-have-announced-their-exit-from-the-nzia/; https://www.fnlondon.com/articles/major-insurers-risk-falling-behind-on-climate-change-as-net-zero-coalition-fights-for-survival-20240201
[1342] https://www.unepfi.org/net-zero-banking/

- Transition the operational and attributable greenhouse gas (GHG) emissions from their lending and investment portfolios to align with pathways to net-zero by 2050 or sooner.
- Within 18 months of joining, set targets for 2030 or sooner and a 2050 target, with intermediary targets to be set every 5 years from 2030 onwards.
- Banks' first 2030 targets will focus on priority sectors where the bank can have the most significant impact, i.e., the most GHG-intensive sectors within their portfolios, with further sector targets to be set within 36 months.
- Annually publish absolute emissions and emissions intensity in line with best practice and within a year of setting targets, disclose progress against a board-level reviewed transition strategy setting out proposed actions and climate-related sectoral policies.
- Take a robust approach to the role of offsets in transition plans.

However, in April 2024, the European Central Bank released a White Paper (*Business as Usual: Bank Climate Commitments, Lending, and Engagement*) which indicated that global banks with climate-related targets had done little to change their business practices to meet their goals: 'Climate-aligned banks do not change their lending or loan pricing differentially compared to banks without climate commitments, suggesting they are not actively divesting. …Further, we find no evidence of a change in interest rates charged by climate-aligned banks to high-emission firms'. The White Paper concluded: 'Our results cast doubt on the efficacy of voluntary climate commitments for reducing financed emissions, whether through divestment or engagement. More broadly, it suggests that voluntary private-sector initiatives may have relatively little impact on decarbonization'.[1343]

In January 2025, Morgan Stanley withdrew from the Net-Zero Banking Alliance, saying that its 'commitment to net zero remains unchanged. We aim to real-economy decarbonisation by providing our clients with the advice and capital required to transform business models and reduce carbon intensity. We will continue to report on our progress as we work towards our 2030 interim financed emissions target'. It followed withdrawals by other top US investment banks, including JP Morgan, Goldman Sachs, Citigroup, Wells Fargo and Bank of America in response political pressure and antitrust concerns following the 2024 US general election.[1344] In response to these withdrawals, GFANZ (the Glasgow Financial Alliance for Net Zero) has lowered its requirements for membership, saying it will now focus on green investment opportunities instead of decarbonisation: 'GFANZ going forward will allow any financial institution working to mobilise capital and lower the barriers to financing energy transition to participate' and become an 'independent principals group, led by CEOs and leaders from financial institutions'. Prior to this, GFANZ expected its members to align their financial activities with the goals of the Paris Agreement which, according to the Intergovernmental Panel on Climate Change, would require them to stop financing oil and gas projects in the US. This was not be acceptable

[1343] https://www.ecb.europa.eu/pub/pdf/scpwps/ecb.wp2921~603e225101.de.pdf; https://www.ai-cio.com/news/ecb-research-finds-climate-aligned-banks-all-talk-no-action/
[1344] https://www.investmentweek.co.uk/news/4392139/morgan-stanley-leaves-net-zero-banking-alliance

to the new Republican government under Donald Trump who has promised to 'drill, baby, drill'. According to Bob Eccles, visiting professor at the University of Oxford's Saïd Business School, said: 'This new pressure from Trump has given a lot of these guys a reason to leave GFANZ. Some of them were just looking for an excuse. They all signed up too quickly, and didn't think through what this would actually mean for them. This whole finance-centric theory of change is flawed. It's not the role of banks and investors to get rid of fossil fuel companies'.[1345] In April 2025, the NZBA announced a series of changes to its framework and principles, including removing a mandatory requirement for banks to align lending and capital markets activities with the goal of limiting global warming to 1.5°C. In October 2025, the NZBA formally ceased operations, when its members voted to transition from a membership-based group to a guidance framework.[1346] At its height in 2024, the NZBA had 140 banks representing $74trn of assets.[1347]

**Multi-national and multi-industry initiatives**

There are also some multi-national and multi-industry initiatives outside the UN's remit.

### Carbon Disclosure Project and the Science Based Targets initiative

First is CDP (Carbon Disclosure Project) which was established in 2000 as an international non-profit organization based in the UK, Japan, India, China, Germany, Brazil and the US to help companies, cities, states, regions and public authorities disclose their environmental impact. It aims to make environmental reporting and risk management a business norm, driving disclosure, insight, and action towards a sustainable economy.[1348]

The Science Based Targets initiative (SBTi) was established in 2015 as a collaboration between CDP, the UN Global Compact, the World Resources Institute (WRI) and the World Wide Fund for Nature (WWF). It aims to help companies set emission reduction targets in line with climate sciences and Paris Agreement goals. It is funded by IKEA Foundation, Amazon, Bezos Earth Fund, We Mean Business coalition, Rockefeller Brothers Fund and UPS Foundation. In 2021, it launched the world's first net zero standard, together with a framework and tools for companies to set science-based net zero targets.[1349] According to SBTi, by 2024, net zero pledges covered 92% of global GDP and 88% of global emissions.[1350] In April 2024, it proposed using 'environmental attribute certificates'[1351]

[1345] https://www.pensionpolicyinternational.com/sustainable-finance-is-braced-for-its-toughest-year-yet/
[1346] https://www.reuters.com/sustainability/cop/net-zero-banking-alliance-stop-operations-after-member-vote-2025-10-03/
[1347] https://www.esgtoday.com/net-zero-banking-alliance-drops-requirement-to-align-financing-with-1-5c/
[1348] https://www.cdp.net
[1349] https://sciencebasedtargets.org/
[1350] https://impact-investor.com/special-report-pension-funds-grapple-with-the-just-transition
[1351] The SBTi defines environmental attribute certificates as 'instruments used to quantify, verify and track the environmental benefits associated with climate mitigation activities or projects. Environmental attribute certificates are used in different chains of custody models with varying traceability, e.g., from models where the activity issuing the certificate is traceable throughout the value chain to models where the certificate is traded separately from the underlying activity, not allowing traceability of the activity issuing the certificate to the value chain. Trading of these certificates may allow buyers to make claims, while also

(which include emission reduction credits) for offsetting certain emissions. This was criticized by those who said SBTi should be prioritising emissions reductions. Others, such as Varma, the Finnish mutual pensions insurance company, said: 'the inclusion of carbon credits in the SBTi framework introduces a new component that, if managed with rigorous oversight and strict criteria, could serve as an additional tool, …while ensuring that the emphasis on direct reductions remains at the forefront of our sustainability efforts'.[1352]

In July 2025, SBTi launched a standard that 'provides clear, actionable science-based guidance for banks, asset owners and managers, private equity firms and other financial institutions to align their lending, investment, insurance, and capital markets activities with avoiding the worst impacts of climate change and achieving net-zero by 2050 at the latest'. Investors had to publicly commit to reaching net zero by 2050, provide near- and long-term targets, and report annually on their progress.[1353] They also had to assess and disclose their exposure to deforestation by 2030. The standard includes a new category for investments in climate solutions, and clearer expectations around engagement, disclosure and the use of transition finance. It also banned project finance or insurance for new oil and gas expansion activities from 2030. Sarah Ben-Moussa at Greenly said: 'for many financial institutions, investing in, primarily, oil and gas, that's going to be a big ask without a transition plan in place'. In addition, the standard moved towards measuring climate progress in dollars, not tonnes of carbon emissions. Under the Financial Institutions Net-Zero Standard, the focus of portfolio eligibility changed from the materiality of the emissions to financial materiality: any activity that generates more than 5% of an investor's total revenues must be covered by the decarbonisation target. Traditionally, decarbonisation targets applied only to portfolios – usually corporate bonds and equities – with a significant level of financed emissions. But the new standard includes sovereign bonds, derivatives, and the capital markets activities of banks. SBTi gives investors the choice between reducing the emissions intensity of the portfolio until it converges with a credible transition pathway, or demonstrating an increase in allocation to assets that support the transition. In the second case, investors must first sort their investments into pre-defined categories, including 'in transition', 'climate solutions', 'net-zero aligned' and 'not aligned'. Each category comes with a requirement to increase the proportion over set timeframes.[1354]

### Institutional Investors Group on Climate Change

Second is the Institutional Investors Group on Climate Change (IIGCC) which was established in 2001 as a forum for collaboration between pension funds and asset managers on issues related to climate change.[1355] In 2005, it and the Carbon Trust worked with

providing financial incentives to interventions that reduce greenhouse gas emissions, promote renewable energy or achieve other sustainability objectives'; https://sciencebasedtargets.org/resources/files/call-for-evidence-environmental-attribute-certificates.pdf

[1352] https://www.ipe.com/news/time-for-sbti-to-stand-aside-says-allianz-si-head-amid-offsets-fallout/10072848.article

[1353] https://www.ipe.com/news/sbti-launches-standard-for-investors-net-zero-targets/10131809.article

[1354] https://www.ipe.com/analysis/the-verdict-on-sbtis-new-standard-for-investors/10132545.article

[1355] https://www.iigcc.org/

Mercer to develop a guide for pension trustees to support them in understanding and addressing climate risk. In 2012, IIGCC established the Global Investor Coalition (GIC) to collaborate on joint international projects focused on climate policy, corporate engagement and investment practices. In May 2019, IIGCC helped to establish the Paris Aligned Investment Initiative (PAII), an investor-led forum to support investors in aligning their portfolios and investment activities to the goals of the Paris Agreement.

In April 2021, IIGCC published the Net Zero Investment Framework (NZIF) for decarbonizing institutional investors' assets. In November 2023, it published a 'users guide' to defining, measuring and investing in climate solutions, building on the NZIF. It estimated that $120trn of investment will be required by 2050 in order to keep the world below 1.5°C. Danielle Boyd, head of climate strategy implementation at IIGCC, said that: 'Without a concerted effort to increase investment into climate solutions, the decarbonization part of that approach is unlikely to happen. But there's a big gap in what this actually means for investors, so this guidance tries to help investors understand how to identify climate solutions, how to measure their impacts, and how to engage with data providers and companies on these issues'. The guidance discussed climate solutions in public equities and corporate fixed income portfolios (together with emissions performance criteria) and their role in corporate transition plans.[1356] In February 2024, IIGCC introduced the Cumulative Benchmark Divergence (CBD) which measures the difference between the decarbonization trajectory implied by a company's emissions target and a climate benchmark over the whole pathway to net zero. This is designed to help investors better identify transition risk in their assets and portfolios.[1357]

In June 2024, IIGCC released NZIF 2.0.[1358] This introduced a Portfolio Decarbonization Reference Target to aid portfolio alignment and investment in climate solutions. It also included guidance for other asset classes, such as sovereign bonds, private equity, and real estate infrastructure. Suggested actions included investor engagement with issuers and other actors in the investment value chain to advance the global decarbonization agenda, such as pressing data providers to increase the quality and consistency of consumption emissions disclosures, 'land use, land-use change, and forestry' (LULUCF), methane emissions reporting, and to develop indicators to better assess criteria set out by the guidance.[1359]

In September 2024, IIGCC finalized materiality-based guidance for investors about addressing Scope 3 emissions in investments, including checking their portfolios' exposure to key 'hotspots', such as particular categories of value chain emissions related to the energy sector, industrials and materials, banking, consumer products and services, and food producers. It pointed out that an asset's value chain emissions, e.g., from the use of a

[1356] https://www.ipe.com/news/iigcc-publishes-investor-guidance-on-climate-solutions/10070079.article
[1357] https://www.ipe.com/news/iigcc-unveils-new-corporate-climate-target-assessment-tool/10071691.article
[1358] https://www.iigcc.org/hubfs/2024%20resources%20uploads/IIGCC_NZIF%202.0_consultation_2024.pdf
[1359] https://www.ipe.com/news/iigcc-finalises-update-to-key-net-zero-guidance-for-investors/10074138.article

company's products, are material to the mitigation of financial risks associated with climate change and should be taken into consideration by investors. It said investors should develop a bespoke strategy to approaching Scope 3 emissions in the context of what is material to their individual portfolios and this should be communicated transparently.[1360]

In March 2025, IIGCC launched a consultation on the Climate Resilience Investment Framework (CRIF) which is intended to encourage more investors to factor climate risk into their investment strategies by outlining the benefits of managing physical climate risks from a financial materiality perspective: 'Reducing physical climate risks across value-chains and encouraging investment in adaptation solutions is part of this framework promotion of systemic resilience as part of the overall objective of climate resilience goals'. The CRIF is designed to complement the Net Zero Investment Framework (NZIF), but also has differences: including target setting as process-based, not outcome-based, reflecting the nuances of climate resilience; encouraging a shift in focus from merely assessing environmental impacts to actively incorporating climate resilience into investment strategies; and integrating the Physical Climate Risk Assessment Methodology (PCRAM)[1361] into existing investor processes.[1362]

In August 2024, the €59bn Danish pension fund PKA withdrew from NZAOA (which it joined in March 2021), citing resource strain. It said that instead it would 'focus on the Institutional Investors Group on Climate Change and its Paris Aligned Asset Owners (PAAO) initiative, to maximize the impact of our resources and collective efforts in climate and biodiversity'. NZAOA and PAAO are Glasgow Financial Alliance for Net Zero (GFANZ) asset owner initiatives that are co-ordinated by IIGCC. This was the fourth departure from NZAOA. The Australian super fund CBUS left in September 2022, the German insurer HanseMerkur left in May 2023, and the Church of England Pensions Board left in June 2023. All said they wanted to concentrate on one asset owner initiative.[1363]

### Global Impact Investing Network and Catalytic Capital Consortium

Third is the Global Impact Investing Network (GIIN) which was established in 2009. It is 'dedicated to increasing the scale and effectiveness of impact investing. [It] builds critical infrastructure and supports activities, education, and research that help accelerate the development of a coherent impact investing industry'. Its members (around 4,000) from 60 countries included asset owners, asset managers, and service providers (with total AUM of $1.5trn in 2024).[1364] Related to this is the Catalytic Capital Consortium (C3). 'Catalytic capital' is defined as 'investment capital that is patient, risk-tolerant, concessionary, and flexible. It is an essential tool to support impact-driven enterprises and organizations that lack access to capital on suitable terms through the conventional marketplace. The aim of

[1360] https://www.ipe.com/news/iigcc-finalises-materiality-based-scope-3-guidance-for-investors/10075466.article
[1361] https://www.mottmac.com/en/insights/topics/pcram-the-industry-methodology-for-climate-resilient-infrastructure-investment/
[1362] https://www.ipe.com/news/iigcc-launches-climate-resilience-framework-consultation/10129263.article
[1363] https://www.pensionpolicyinternational.com/danish-pension-fund-leaves-net-zero-asset-owner-alliance/
[1364] https://thegiin.org/

catalytic capital is to unlock impact and additional investment that would not otherwise be possible, strengthening communities, expanding opportunity and economic growth, and fueling innovation that advances the wellbeing of people and the planet, while laying the groundwork for mainstream investors to participate in transformative investments'. C3 seeks to address the annual funding shortfall of $2.5trn in developing countries that is preventing the world from reaching the UN Sustainable Development Goals.[1365] According to Mónica Vásquez del Solar, head of strategy and impact at Social Nest Foundation, 'These investments are made by investors willing to take on greater risk, those capable of investing in for example early-stage startups, more transformative business models, or early-stage investment vehicles that face challenges in securing their first round of funding. Without these investors, entrepreneurs and impact fund managers would find it impossible to build a track record that might allow them to scale their models and maximize impact'.[1366]

In October 2025, GIIN's *State of the Market 2025* report revealed strong growth in impact-related private equity investments, with pension funds supplying the largest pool of impact capital, followed by insurance companies and family offices. AUM in impact assets within a sample group of 429 respondents increased to $448bn in 2025 from $249bn in 2024, and $129bn in 2019. Further, 72% of investors expressed satisfaction with the financial performance of their impact portfolios, while 90% reported satisfaction with their impact performance. Impact investors were predominantly based in high-income countries (85%), particularly in North America and Western Europe, and tended to invest domestically. Energy was the most targeted sector, with 57% of respondents making at least one investment, followed by agriculture and forestry with 55%, and financial services and healthcare, which both received 51%. Private equity allocations grew from $15.2bn to $79.5bn, while private debt and public debt rose also saw big increases. Real assets nearly doubled, reflecting a shift toward tangible, climate-aligned investment.[1367]

### Network for Greening the Financial System and Climate Financial Risk Forum

Fourth is the Network for Greening the Financial System (NGFS) set up in 2017.[1368] This is a network of 114 central banks and financial supervisors which aims 'to help strengthen the global response required to meet the goals of the Paris Agreement and to enhance the role of the financial system to manage risks and to mobilize capital for green and low-carbon investments in the broader context of environmentally sustainable development. To this end, the Network defines and promotes best practices to be implemented within and outside of the Membership of the NGFS and conducts or commissions analytical work on green finance'.[1369] [1370] Related to this is the Climate Financial Risk Forum (CFRF), an

[1365] https://www.macfound.org/programs/field-support/impact-investments/catalytic-capital-consortium/; https://catalyticcapitalconsortium.org/
[1366] https://impact-investor.com/viewpoint-the-transformative-power-of-catalytic-capital
[1367] https://impact-investor.com/giin-report-impact-investing-surges-despite-global-headwinds
[1368] https://www.ngfs.net/en
[1369] https://www.ngfs.net/en
[1370] NGFS identifies seven different transition scenarios: Current Policies, Nationally Determined Contributions, Fragmented World, Delayed Transitions, Low Demand, Below 2°C, and Net-Zero 2050. Of

industry forum jointly convened by the UK Prudential Regulation Authority and Financial Conduct Authority.[1371] On 17 January 2025, three days before the inauguration of Donald Trump as the 47th President of the United States, the US Federal Reserve Board announced its withdrawal from the NGFS, on the grounds that 'the work of the NGFS has increasingly broadened in scope, covering a wider range of issues that are outside of the Board's statutory mandate'. [1372]

### Climate Finance Leadership Initiative

Fifth is the Climate Finance Leadership Initiative (CFLI) formed in 2019 by Michael R. Bloomberg in his role as UN Special Envoy on Climate Ambition and Solutions, at the request of the UN Secretary General, António Guterres, to 'support a global mobilization of private finance in response to the challenge of climate change' both in industrialized countries and the Global South. It brings together leading private sector institutions (including corporates, commercial and investment banks, insurers, asset managers, and asset owners), policymakers and development finance institutions. Founding members included Allianz Global Investors, AXA, Bloomberg, Enel, Goldman Sachs, Japan's Government Pension Investment Fund (GPIF), HSBC, and Macquarie. [1373]

### Mirova and Robeco fund manager-led initiative to standardize the calculation of avoided emissions

Sixth is a fund manager initiative to establish a standardized method for calculating avoided emissions in commercial environmental projects, such as electric car manufacturing. The initiative is led by Mirova and Robeco, and includes Edmond de Rothschild, Natixis CIB, Lombard Odier, Comgest, Man Group, Sienna IM and Caisse des Dépôts. It aims to develop a standardized toolkit to calculate avoided emissions and then to encourage data providers to introduce avoided-emissions (i.e., low-carbon) solutions based on the metrics. The toolkit will also be used by fund managers with exposure to asset classes, such as infrastructure and project financing. Two consultancies, I Care by Bearing Point and Quantis, were appointed in January 2024 to build the database and toolkit. The database will initially consider 80 low-carbon solutions, such as biomass energy, recycled plastic and low-carbon concrete. As an example, the group said that if it is relevant to take into account all the resources and the recyclability of components that come into play in the production of an electric vehicle, it is also relevant to understand and measure the carbon emissions that can be avoided by an electric vehicle in a transport sector still very dependent on thermal engines. Lucian Peppelenbos, climate and biodiversity strategist at Robeco, said: 'Avoided emissions are the missing piece of the puzzle when it comes to

---

these, only the Low Demand and the Net-Zero 2050 scenarios are compatible with the 1.5°C global warming goal.

[1371] https://www.bankofengland.co.uk/climate-change/climate-financial-risk-forum; https://www.fca.org.uk/publication/corporate/quantitative-climate-scenario-analysis-financial-decisions-case-studies.pdf

[1372] https://www.federalreserve.gov/newsevents/pressreleases/bcreg20250117a.htm

[1373] https://www.bloomberg.com/cfli/about/

facilitating transition finance. At a global level, much more capital needs to go into climate solutions. This metric can help to direct capital flows towards companies that provide the most effective climate solutions'. Fees will be 'reasonable' to encourage widespread market use.[1374]

### Allianz's dashboard to track the transition pathway to net zero

Seventh is SAMEpath, a dashboard released by Allianz in January 2024 to track the transition pathway to net zero by 2050 across more than 50 industries. The tool outlines the emissions reductions required to hit targets, as set out in the 2015 Paris Agreement. It has a number of functions, including customized searches on climate scenarios, the identification of climate transition risks across sectors and the economy, and the carbon price required to achieve a reduction in emissions. The tool can form the basis for business, investment and underwriting decisions worldwide.[1375]

### International Organization of Securities Commissions' initiative for companies world-wide to adopt sustainability-related financial disclosure standards

Eighth is the International Organization of Securities Commissions (IOSCO) which cover 95% of the world's securities markets. In December 2023, it announced that around 130,000 companies world-wide would adopt the sustainability-related financial disclosure standards, across both trading and capital raising, developed by the International Sustainability Standards Board. Erkki Liikanen, chair of the IFRS trustee board, said: 'By endorsing the ISSB standards, securities regulators around the world are working to achieve the consistency and comparability of information that capital markets demand'.[1376] However, in contrast to the double materiality approach of the EU, the ISSB has adopted a single materiality approach, where companies report only on the impact of a sustainability topic on their business. There are also differences between securities commissions at the national level. For example, in March 2024, the Securities and Exchange Commission (SEC) released the first climate disclosure rules for US corporates to 'provide investors with consistent, comparable, and decision-useful information, and issuers with clear reporting requirements'.[1377] The disclosures are less onerous than the original proposals, e.g., only large public companies are required to calculate and report certain greenhouse gas emissions, and then only if they are considered 'material'; value chain greenhouse gas emissions are excluded; and the climate expertise of the board of directors does not have to be reported. This differs from both EU requirements and the new IFRS S2 rules.[1378]

---

[1374] https://www.funds-europe.com/news/fund-managers-select-consultants-to-create-missing-piece-of-climate-finance-puzzle; https://www.responsible-investor.com/investor-backed-avoided-emissions-data-project-kicks-off/

[1375] https://www.investmentweek.co.uk/news/4168121/allianz-unveils-dashboard-track-transition-net-zero

[1376] https://www.fnlondon.com/articles/more-than-100000-firms-to-use-new-sustainability-disclosure-standards-says-global-securities-chair-issb-iosco-20230725

[1377] https://www.pensionpolicyinternational.com/how-sustainability-disclosures-and-regulations-benefit-investors/

[1378] https://www.theguardian.com/business/2024/mar/06/us-sec-climate-change-emissions-disclosure

## Accounting for Sustainability

Ninth is Accounting for Sustainability (A4S)'s 2024 Sustainability Principles Charter for the UK bulk annuity process which establishes guiding principles for the bulk annuity process focusing on transparency, decision making, reporting and engagement, and collaboration.[1379] This is an initiative that has brought together schemes, insurers and advisers. Founding signatories include pension schemes (Cancer Research Pension Scheme, Church of England Pensions Board, HSBC Bank Pensions Scheme, Railpen, and Railways Pension Scheme), insurers (Aviva, Just Group, Legal & General, Pensions Insurance Corporation, Standard Life, and Rothesay), and advisers and trade bodies (Cardano, Aon, Hymans Robertson, LCP, Mercer, Redington, the Pensions and Lifetime Savings Association and the Pi Partnership Group). The motivation for the charter was concern over whether bulk annuity transactions would maintain the sustainability strategies established by pension schemes. and how they would then be transferred over in a bulk annuity process.[1380]

In February 2025, signatories of the Sustainability Principles Charter agreed to adopt the Bulk Annuity Sustainability Survey (BASS), reducing the number of surveys used by different advisers to assess insurers' sustainability credentials for the bulk annuity process from 10 to 1. The aim is to improve the efficiency of the process and the range of information available for comparing insurers' responses on sustainability.[1381]

## Net Zero Engagement Initiative

Tenth is the Net Zero Engagement Initiative (NZEI) which launched in March 2023. NZEI's aim is to 'build on and extend the reach of investor engagement beyond the Climate Action 100+ focus list, including more companies that are heavy users of fossil fuels, contributing to demand for its products. The objective is to help investors align more of their portfolio with the goals of the Paris Agreement, as set out by their net zero commitments. …Under the [IIGCC's] Net Zero Investment Framework (NZIF)…investors

[1379] There are four key principles:

1. Transparency: Transparency of values, principles and investment beliefs in relation to sustainability, as well as ongoing commitments that may guide future policy and practice affecting sustainability approaches.
2. Decision making: Evidence and understanding of how sustainability considerations are incorporated into investment analysis and decision-making processes, and investment stewardship activity.
3. Reporting and Engagement: Ongoing reporting and engagement to key stakeholders on sustainability commitments beyond the point of transaction.
4. Collaboration: Commitment to ongoing engagement across the pension sector as responsible investment best practice evolves.

Source: https://www.accountingforsustainability.org/en/about-us/our-networks/asset-owners-network/bulk-annuity-sustainability-principles-charter.html.

[1380] https://www.ipe.com/news/pension-insurers-charter-commits-to-sustainable-pension-risk-transfers/10071329.article; https://www.accountingforsustainability.org/

[1381] https://www.ipe.com/news/sustainability-principles-charter-signatories-adopt-bulk-annuity-sustainability-survey/10128685.article

should engage, or classify as aligned, assets that account for 70% of financed emissions in material sectors. ...The central ask of investor engagement via NZEI is a corporate net zero transition plan'.[1382] In May 2024, IIGCC released guidance (*Net Zero Investment Framework for the Private Debt Industry*) to the private debt industry (involved in direct lending, venture/growth debt, opportunistic credit, structured credit, fund financing and private placements) on establishing a cohesive framework for setting and delivering net zero commitments. The guidance includes a 'three-way engagement model' between lenders, portfolio companies (PCs) and private equity (PE) sponsors, includes climate disclosures in loan documentation, and encourages the consistent sharing of standardized climate/ESG data.[1383]

### Just transition networks

Eleventh are a number of just transition networks. For example, in 2022, a dozen UK pension funds, led by the Church of England Pensions Board, established the Emerging Markets Just Transition Investment Initiative to support climate transition in emerging markets. Similarly, in 2023, the Impact Investing Institute established the Just Transition Criteria in collaboration with 21 global financial institutions.[1384] At the UK Impact Investor Forum 2024, pension funds emphasized the importance of taking into account the just transition in their investment strategies, given the risks to members' future health and economic wellbeing associated with global warming and the energy transition. This meant looking beyond maximizing investment returns to consider the long-term interests of members.[1385] Another example is Pensions for Purpose which was established in 2017 and is part of 'the global movement for an inclusive, equitable, and regenerative economy'.[1386] It is a public B Corp[1387] and meets B Lab's standards for social and environmental impact. In January 2025, it published *Integrating Nature & Biodiversity into Investment – An Asset Owner Perspective*.[1388] This found that 65% of asset owners were incorporating nature and biodiversity into their sustainability strategies, while a further 20% plan to do so. Bruna Bauer, research manager at Pensions for Purpose, said: 'One key issue is that nature and biodiversity are still primarily viewed through the lens of risk mitigation rather than opportunity. It's essential to highlight the financial value of preserving and restoring ecosystems'.[1389]

[1382] https://www.iigcc.org/net-zero-engagement-initiative
[1383] https://www.iigcc.org/resources/nzif-private-debt-industry; https://www.portfolio-institutional.co.uk/esg-hub/climate-change-investor-group-sets-out-private-debt-framework/
[1384] https://impact-investor.com/special-report-pension-funds-grapple-with-the-just-transition
[1385] https://impact-investor.com/impact-investor-forum-leading-pension-funds-on-managing-a-just-transition/
[1386] https://www.pensionsforpurpose.com/; https://www.pensionsforpurpose.com/knowledge-centre/press/2018/09/01/a-history-of-pensions-for-purpose-so-far/
[1387] https://www.bcorporation.net/en-us/certification/
[1388] https://www.pensionsforpurpose.com/assets/uploads/2025-01-30-Impact-Lens-Biodiversity.pdf
[1389] https://www.pensionpolicyinternational.com/asset-owners-increasingly-aware-of-risks-of-biodiversity-loss-report-says/

## International collaboration between pension funds

Twelfth, pension funds have begun to collaborate internationally to deliver net zero. An example is 'Mobilising pension capital for net zero: A policy blueprint for the UK'. This is a joint venture by a around a dozen large UK and Australian funds, pension-fund-owned investors, and the Pensions and Lifetime Savings Association (PLSA). It was set up in October 2024 in response to a new UK government which has plans to rapidly increase clean power. The government wants to work with the private sector to double onshore wind, triple solar power, and quadruple offshore wind by 2030. It also wants to expand new net zero technologies, such as hydrogen and carbon capture and storage. This will require tens of billions of pounds of investment annually. The signatories to the blueprint collectively represent £1.7trn in pension savings from around 30 and 10 million workers in the UK and Australia, respectively. Many are already major investors in the infrastructure of each country. The blueprint's 20-point plan seeks an active and coordinated approach by government, investors and industries across planning, climate, energy, fiscal and industrial decarbonization policy. This would help unlock further investment in the UK's net zero transition, drive economic growth and deliver appropriate risk-adjusted returns on workers' retirement savings. The objective is a pipeline of investable projects in which pension fund capital can participate in line with their fiduciary duty to members. Gregg McClymont, executive director for public affairs Europe at IFM Investors, one of the signatories to the blueprint, said: 'Our recommendations are led by the call for the government to take a long-term approach with respect to energy transition investments. … Such an approach will encourage the co-investments which will be an important part of energy transition finance. … [T]he blueprint's broader aim is to deepen dialogue between government and pension capital on the financing of the energy transition. After all net zero will be reached project-by-project, sector-by-sector over the next 25 years'.[1390]

## Industrial Transition Accelerator

Thirteenth is the Industrial Transition Accelerator (ITA), whose aim is to 'galvanize leaders from across industry, finance, and governments to scale the decarbonization of heavy-emitting industries. Backed by a vast network of climate innovators, industry leaders and technical experts, the ITA seeks to unlock investment and drive solutions across six critical sectors that account for roughly 30% of global emissions: aluminum, cement, chemicals, steel, shipping, and aviation'.[1391] It wants governments to implement measures that stimulate the demand for green products. It estimates that such measures could unlock up to $1trn in green investments by 2030 and drive the development of over 500 sustainable industrial facilities in sectors, such as steel, aluminium, and aviation.[1392] The ITA was launched at COP28 in December 2023.

[1390] https://www.ipe.com/analysis/viewpoint-pension-funds-must-be-at-the-centre-of-the-uk-investment-debate/10076163.article
[1391] https://ita.missionpossiblepartnership.org/
[1392] https://funds-europe.com/cop29-uk-launches-carbon-market-integrity-priciples

### The OECD's Climate Adaptation Investment Framework

Fourteenth is the OECD's Climate Adaptation Investment Framework (CAIF) which 'aims to support governments' efforts to unlock investment in adaptation to build resilience to climate change. Building upon the foundation of the OECD's Policy Framework for Investment and the Foreign Direct Investment (FDI) Qualities Policy Toolkit, it identifies the key domestic policies that are particularly relevant for enabling climate change adaptation investment. The scope of the CAIF includes both public and private investment, given that both sources will be critical for climate adaptation. …Increased public and private investment will be needed in activities that help to reduce harms or realise any potential opportunities due to the impacts of climate change ('adaptation investments'), such as the development of climate-resilient infrastructure, food systems and supply chains. Adaptation investments are economically and socially worthwhile. The benefits will be context specific, but there is a large volume of economically worthwhile investment opportunities: one study identified USD 1.8 trillion of adaptation investments, with benefit-cost ratios ranging from 2:1 to 10:1'.[1393]

### University-based research programs on climate change and solutions

A number of universities have begun programs of research on climate change and solutions. Examples are Princeton University's Net-Zero America Project,[1394] MIT's Climate Pathways Project,[1395] with its En-ROADS online climate solutions simulator,[1396] and the London School of Economics and Political Science (LSE)'s Grantham Research Institute on Climate Change and the Environment.[1397] In 2017, the Global Research Alliance for Sustainable Finance and Investment (GRASFI) was established by a network of global research universities 'in order to promote rigorous and highly impactful academic research on sustainable finance and investment'.[1398]

Another example is the EDHEC Climate Institute established by EDHEC Business School. In 2025, it published a new framework for probabilistic climate scenario analysis in a study entitled *How to Assign Probabilities to Climate Scenarios* by Riccardo Rebonato, Lionel Melin, and Fangyuan Zhang. Using a large meta-dataset of 5,905 Social Cost of Carbon (SCC) estimates from 207 academic studies, the study utilized two methodologies: one based on expert assessments of carbon pricing, and the other on a maximum-entropy approach that requires minimal prior assumptions. These approaches produced consistent estimates of the likelihood of different climate outcomes by 2100. The key findings from the study are:

---

[1393] https://www.oecd.org/en/publications/climate-adaptation-investment-framework_8686fc27-en.html
[1394] https://netzeroamerica.princeton.edu/
[1395] https://mitsloan.mit.edu/centers-initiatives/sustainability-initiative/mit-climate-pathways-project
[1396] https://www.climateinteractive.org/en-roads/; https://en-roads.climateinteractive.org/scenario.html?v=24.1.0
[1397] https://www.lse.ac.uk/granthaminstitute/
[1398] https://sustainablefinancealliance.org/

- A 35-40% chance that temperatures will rise beyond 3°C by 2100, a level with severe implications for global stability and risk management.

- The 1.5°C target is technologically feasible, but highly improbable without rapid, radical policy shifts.

- A median warming estimate of 2.7°C, indicating significant departure from the Paris Agreement goals.

- Physical climate damages outweigh the economic costs of transition – underscoring the need for realistic climate finance frameworks.

To demonstrate the model's applicability, the authors aligned their framework with the structure of the Oxford Economics climate scenarios. They find that more than 90% of the probability mass is allocated to scenarios characterized by limited or delayed abatement. The authors conclude that without probabilities, scenarios are limited in their ability to inform risk-adjusted decision-making.[1399]

A further example is The Green Finance Research Advances is an International Research Conference for academics and professionals, co-organized by Banque de France and Institut Louis Bachelier, with the participation of Institut de la Finance Durable and the Institute for Climate Economics-I4CE.[1400]

### Industry-based research programs on climate change and solutions

More recently, private-sector companies have started devoting resources to climate change research.

One example is scenario modelling by Club Vita. In December 2025, Amy Walker, an actuary at the firm, discussed Club Vita's updated *Hot and Bothered?* report. She pointed out that: 'Many of the climate-related events and health impacts we now face have never happened before and will not be captured by simply projecting historical trends. This is where narrative-based scenario modelling becomes essential. It is one of the most powerful tools we have to make sense of uncertainty. By exploring the impact of possible future events, we can stress test our assumptions while understanding how these events might play out over time. For longevity in particular, crafting scenarios can help us grapple with big-picture forces like climate change, shifting demographics, and evolving public health trends, all of which unfold over decades with little historical precedent'. She argued that scenario analysis can help pension funds and (re)insurers integrate the issues of climate change and resource constraints into their broader risk management frameworks.

The report discussed three scenarios (but did not apply any probabilities to the scenarios):

[1399] https://climateimpact.edhec.edu/publications/how-assign-probabilities-climate-scenarios
[1400] https://climateinstitute.edhec.edu/events/green-finance-research-advances-gfra

- Scenario 1: Sustained stagnation. Under this scenario, limited adaptation and mitigation lead to severe global impacts. Initially, there is a lack of response to resource and environmental risks until they cause significant societal harm. By the time the world reacts, climate change has caused crop failures and food shortages. Extreme temperature fluctuations and prolonged heatwaves lead to increased mortality, especially among the elderly, many of whom are pushed beyond their 'frailty point', where heat exhaustion accelerates morbidity. Although current cancer vaccines show promise, their impact is hindered by manufacturing constraints and diet changes due to food scarcity. This results in an upward trend in both cancer and cardiovascular disease. Meanwhile, antibiotic resistance rises. Despite initial drug breakthroughs using artificial intelligence, the development of new antibiotics remains limited. Warmer climates also bring new infectious diseases to the UK, increasing infection rates back to levels not seen in over a century. Pandemics like Covid-19 become common, exacerbated by strained resources that undermine NHS capacity. As a result, the quality of care for age-related conditions, such as frailty and neurodegenerative diseases like Alzheimer's, deteriorates further.

- Scenario 2: Turbulent times. In this scenario, some adaptation occurs but progress is too slow to fully offset the limitations of finite resources and the climate impacts already locked into the system. This scenario can be viewed as largely following the current course, where political will for adaptation and mitigation exists, but progress moves slowly. This gradual pace of change leads to a range of consequences, including rising fuel prices and intensified competition for resources. In the UK, these pressures translate into financial strain and funding limitations for the NHS. At the same time, reduced access to and higher costs of imported food stocks negatively affect public health. Lower-income groups face challenges affording their basic needs, leading to stagnating life expectancy.

- Scenario 3: Rapid response. This more optimistic scenario envisions rapid (but plausible) response to climate change, driven by public awareness, technological innovation, and decisive legislative action. These efforts lead to meaningful environmental improvements and health benefits. Increased adoption of electric vehicles, public transport, and active travel methods (such as walking and cycling) lead to better health and cleaner air. At the same time, significant improvements in green energy availability and healthier diets also reduce greenhouse gas emissions. The UK invests in better protection against extreme temperatures, enhancing crop security and home insulation. This results in fewer cold and heat-related deaths, as well as more efficient emergency services. Improved diet, exercise, and air quality lead to lower incidences of cancer, cardiovascular disease, dementia, and respiratory diseases. Overall, these factors contribute to a smooth projection of longevity, consistent with a fast and orderly transition to a sustainable future including life expectancy increases.

The report then presented the impact of pension scheme liabilities under each scenario. Under sustained stagnation, liabilities fall by 9%. In turbulent times, liabilities fall by 1%.

Under rapid response, liabilities rise by 7%. Walker, concluded: 'Scenario analysis is an effective way to try to quantify the potential impact of risk associated with climate change. It also provides a more accessible way of visualizing the possible future effect of longevity risk and is a useful way to stress test risk management plans'.[1401]

**COP28 – December 2023**

In December 2023, COP28, the 28th United Nations Climate Change Conference, took place in Dubai, United Arab Emirates. The outcome is the UAE Agreement or Consensus, a key component of which is the Global Stocktake, a progress report on climate change measures since the signing of the Paris Agreement in 2015 and what measures are needed to fill the gaps. The UAE Agreement has the following key components:[1402]

- The pathway to 1.5°C

The agreement recognizes that to avoid breaching 1.5°C by 2050 requires global greenhouse gas emissions to peak before 2025, followed by deep, rapid and sustained reductions in emissions of 43% (relative to 2019 levels) by the end of 2030, by 60% by 2035, before reaching net-zero carbon dioxide emissions by 2050. Developed nations are expected to take a lead in the 'transition away' from fossil fuels and provide technological and financial support to help developing nations follow them. All countries are expected to develop updated national climate plans (called Nationally Determined Contributions (NDCs)) by 2025, taking account of different national circumstances, pathways and approaches.

- The future of fossil fuels

For the first time in a UN climate declaration, the agreement specifically references the need to reduce global reliance on all fossil fuels – coal, gas, and oil – in order to combat climate change, and, in particular, accelerate moves to 'phase-down unabated coal power'. This is in line with the 'ratchet' mechanism in the Paris Agreement which requires countries individually and collectively to continuously increase their efforts to transition away from fossil fuels in order to achieve the 2050 target. There are caveats, however. For example, the final text of the agreement 'recognises that transitional fuels can play a role in facilitating the energy transition, while ensuring energy security', which is seen as a concession to fossil fuel-dependent countries and new gas-fired power generation projects. There are also potential loopholes. For example, the call to transition away from fossil fuels exclusively refers to 'energy systems', thereby excluding any mention of non-energy uses of fossil fuels, such as plastics and transport.

[1401] https://lminvestor.com/still-hot-and-bothered/

[1402] This section is drawn from: https://www.investmentweek.co.uk/news-analysis/4156897/cop28-agreed-climate-summit-dubai; https://impact-investor.com/cop28-pledges-aplenty-now-for-the-action

- Fossil fuel subsidies

The agreement calls for 'phasing out inefficient fossil fuel subsidies that do not address energy poverty or just transitions, as soon as possible'. This follows on from COP26's recognition of the urgent need to transition public funds away from supporting carbon-intensive industries and towards clean energy solutions. The challenge is significant, however, since global subsidies for fossil fuel consumption exceeded $1trn in 2022, a record high according to the International Energy Agency. The term 'inefficient' has been criticised for being a potential loophole, given its ambiguity.

- Carbon capture, removal, and abatement

The agreement calls on countries to support global efforts to develop carbon capture and storage, carbon removals and abatement technologies 'particularly in hard-to-abate sectors' – although these are not defined.

- Renewables and clean technologies

The agreement calls for support for new targets to triple renewable energy capacity and double the annual rate of energy efficiency improvements by 2030.[1403] These are accepted as challenging targets, but are believed to be achievable if supported by strong policy, investment and planning reforms. It also calls for the accelerated use of 'zero and low emission technologies, including inter alia, renewables, nuclear… and low carbon hydrogen production' to help reduce greenhouse gas emissions, and for the accelerated reduction in road transport emissions 'including through development of infrastructure and rapid deployment of zero and low emission vehicles'. There is also strong support for wind, solar, and energy storage systems that aid the transition away from fossil fuels, with the added bonus that their costs 'have fallen continuously'.

- Methane and non-$CO_2$ emissions

Methane has a far greater impact on global warming than $CO_2$. The agreement calls on countries to support global efforts to accelerate and 'substantially' reduce non-$CO_2$ emissions 'including in particular methane emissions' by 2030. This implicitly targets oil and gas producing countries and companies whose pipeline leaks and flaring are a key source of global methane emissions. It also calls on agriculture, another major contributor, to reduce methane emissions. Major global dairy companies, such as Danone, Kraft Heinz and Nestle, have committed to reporting on their success in reducing their own methane emissions. The Global Cooling Pledge was agreed by 63 countries at the conference with the aim of reducing other key greenhouse gases, such as hydrofluorocarbons (HFCs) and other F-gases which are used in air conditioning and refrigeration.

[1403] The International Renewable Energy Association estimates that an average of 1,000 gigawatts of renewable power capacity needs to be built globally every year until 2030; https://www.ft.com/content/6873d96e-3e40-45c6-9d84-8ce27b7b23e1

- Nature, agriculture, and food systems

The agreement also includes text explicitly linking climate and nature, and offered support for the international goals set out in the Kunming-Montreal Global Biodiversity Framework (KMGBF),[1404] adopted by 188 countries at the UN Biodiversity Conference COP15 in Montreal, Canada, in December 2022. The KMGBF commits the 196 countries that are signatories to the Convention on Biological Diversity (CBD) to develop National Biodiversity Strategies and Action Plans (NBSAPs) for achieving the 23 targets set by the KMGBF, which included protecting 30% of the land and oceans and recover 30% of the planet's degraded ecosystems by 2030 (the 30x30 target).[1405] The text recognises the importance of 'conserving, protecting and restoring nature and ecosystems towards achieving the Paris Agreement goal, including through enhanced efforts towards halting and reversing deforestation and forest degradation by 2030'. It also emphasises the importance of 'ensuring social and environmental safeguards' for nature-based climate solution projects, and invites countries to 'preserve and restore oceans and coastal ecosystems' as a key climate mitigation action. However, while recognizing the vulnerability of food production to the negative impacts of climate change and the need to protect, conserve and preserve water systems, there is little reference in the text about how to transform food systems to reduce emissions and end deforestation.

- International trade

The text says that 'measures taken to combat climate change, including unilateral ones, should not constitute a means of arbitrary or unjustifiable discrimination or a disguised restriction on international trade'. The conference was concerned to avoid countries introducing protectionist measures in the name of climate change mitigation. One potential example of this is the 2022 US Inflation Reduction Act (IRA) which promised $370bn in energy infrastructure investment related tax credits over 10 years, although these would mainly benefit US businesses and tax-exempt organizations, like pension funds, which could take advantage of the tax credits from these investments.[1406] Similarly, the EU's introduction of a Carbon Border Adjustment Mechanism (CBAM) in 2026 is concerning developing economies because it could involve import levies on their goods and services if they fail to meet EU climate regulations and standards. While the agreement did not explicitly oppose CBAMs, it did call for greater 'transboundary cooperation' to meet the Paris goals and for a recognition that developing economies 'have significant capacity constraints' when trying to decarbonize.

[1404] https://www.cbd.int/gbf/. Biodiversity is discussed in more detail below.
[1405] https://www.unep.org/un-biodiversity-conference-cop-15, https://www.cbd.int/conferences/2021-2022
[1406] https://www.pensionpolicyinternational.com/how-sustainability-disclosures-and-regulations-benefit-investors/

- Circular economy and sustainable lifestyles

The text notes 'the importance of transitioning to sustainable lifestyles and sustainable patterns of consumption and production in efforts to address climate change, including through circular economy[1407] approaches, and encourages efforts in this regard'.

- Carbon markets and offsetting

A carbon market trades carbon credits, in which the owners of projects delivering reductions in $CO_2$ from the atmosphere can sell credits for this which can then be purchased by $CO_2$ emitters and hence used to offset (i.e., compensate for) those emissions.[1408] Article 6 of the Paris Agreement covered carbon credit trading between nations and organizations, but the terms have not been formally agreed, and hence the market is still largely an informal one. Indeed, COP28 deferred discussions again until COP29 in Azerbaijan. The main concerns relate to verification and transparency, i.e., ensuring that projects are delivering the promised emission reductions and preventing the issuance of unjustified credits. An example of a current practice that needs to end is 'double-counting', where both the selling and purchasing country or organization claim emissions reductions from the same credits. The absence of formally regulated markets reduces to some extent the incentive to invest in carbon offset[1409] projects.

- Climate adaptation

The agreement established a new Global Goal on Adaptation, requiring countries to establish climate adaptation plans by 2025 and implement them by 2030, via their updated NDCs. The goals cover issues such as poverty eradication, gender equality, nature-based

[1407] The circular economy is discussed in more detail below.

[1408] One carbon credit constitutes the reduction, avoidance or removal of one tonne of carbon dioxide or its carbon dioxide-equivalent ($CO_2e$). The reduction, avoidance or removal must be permanent, additional to that which was going to happen in any case, and be verifiable. Carbon pricing mechanisms covered around 20% of global emissions in 2023 (*Financial News*, 27 November 2023, Issue 1359, p9).

[1409] The carbon offset market is believed to originate with US power company Applied Energy Services (AES) which had the idea of planting a forest to absorb the $CO_2$ produced by its Connecticut-based coal-fired power plant. Due to the cost of land in Connecticut, in 1989, it paid 40,000 farmers to plant trees in Guatemala. Carbon offsetting was sanctioned by the 1997 Kyoto Protocol and the UN Clean Development Mechanism. In 2020 – based on a proposal by former Bank of England governor, Mark Carney – the Taskforce on Scaling Voluntary Carbon Markets established to create a formal market for offsets. Today most carbon credits are bought from developers using brokers. Oil companies (e.g., BP and Shell) and the Saudi government have carbon trading desks. McKinsey has predicted that the value of voluntary offsets could rise from $2bn to $50bn in 2030. There is, however, concern that aggressive tactics might be used to relocate local and indigenous people in order to plant trees and create credits. Further, REDD ('reducing emissions from deforestation and forest degradation') projects have to demonstrate that they genuinely conserve forests by 'proving' that the forests would otherwise have been cut down. This is achieved by measuring forest loss in an unguarded reference area. A newspaper investigation in 2023 claimed that more than 90% of rainforest offsets certified by Verra, the world's largest certifier, did not involve genuine carbon reductions and that two-thirds of the carbon credits generated over a decade did not offset any significant pollution; https://www.telegraph.co.uk/environment/2024/04/21/carbon-offsetting-greenwashing-private-jet-celebrity/

solutions, climate resilient agriculture and food systems, water security, and reducing climate impacts on health, ecosystems, biodiversity, and human infrastructure. However, there was lack of detail on how this was going to be financed.

- Climate finance, and loss and damage

COP28 agreed to set up a global Loss and Damage Fund, through which vulnerable countries facing climate impact costs could apply for financial support. At the conference, richer countries committed $792m to the fund. However, the annual cost of losses and damages from climate impacts for developing nations is estimated to be $400bn.

The agreement also lacked a clear financial program to support countries engaged in energy transition and climate adaptation activities. Many developing countries, including the Alliance of Small Island States (AOSIS), were concerned about the limited progress on climate finance, adaptation, and loss and damage. However, the text of the agreement only requires developed countries to 'provide such support voluntarily', although they 'should take the lead in mobilizing climate finance from a wide variety of sources' and that this 'should represent a progression beyond previous efforts'.

The COP27 global climate agreement signed in Egypt in November 2022[1410] had estimated that the global transition to a low-carbon economy would require annual investments of $4-6trn, or approximately 4-6% of 2022 global GDP of $95trn.[1411] Yet developed countries are still failing to reach an agreed goal to jointly raise $100bn in climate finance annually.[1412]

Kieron Boyle, CEO of the Impact Investing Institute, who attended the summit said that key themes discussed by financial services industry leaders, regulators, and policymakers included the need for more effective capital, greater collaboration among financial market actors, governments and civil society, as well as improved risk-sharing mechanisms between the public and private sectors. Much of the heavy lifting in capital mobilization will need to be via mechanisms such as blended finance and catalytic capital. Funding and guarantees from developed world governments and multilateral development finance institutions to leverage much larger flows of private finance into climate change investments is seen as crucial, especially in low-income countries, where perceptions of high investment risk are blocking private capital flows.

On the opening day of COP28, the UAE announced that it would create a $30bn climate-related investment fund called Alterra,[1413] with the aim of attracting $250bn of investment in carbon emissions reductions and climate resilience projects by 2030. The fund is seeking to make profits from these climate projects, rather than being a development initiative.

[1410] https://unfccc.int/cop27
[1411] https://www.statista.com/statistics/268173/countries-with-the-largest-gross-domestic-product-gdp/
[1412] The International Energy Agency estimates that the public sector will have to contribute 30% of the total global climate finance needed, with the rest coming from the private sector; https://www.ft.com/content/6873d96e-3e40-45c6-9d84-8ce27b7b23e1
[1413] https://www.alterra.ae/

Launch partners include BlackRock, Brookfield and TPG. The UAE hoped its presence as an investor would be catalytic, giving others the confidence to invest too. A $5bn component of the total will be used to provide risk mitigation capital to incentivize investment flows into developing countries. One of the first projects will be the development of 6 gigawatts of clean energy capacity in India.

Existing funds received additional funding commitments: the Green Climate Fund[1414] has pledges totalling $12.8bn from 31 countries; the Least Developed Countries Fund[1415] and Special Climate Change Fund[1416] have combined pledges of $174m; and the Adaptation Fund[1417] has pledges of $188m.

**2024 developments in sustainability**

In January, the Institut Rousseau published a report entitled *Road to Net Zero* which estimated that the EU needed to invest €1.5trn per year (around 10% of GDP) in order to reach net zero by 2050. The main categories are transport (c€700bn), buildings, (c€425bn), energy production (c€180bn), and agriculture (c€160bn).[1418] In February 2024, the Institute for Climate Economics (I4CE) estimated that, in order to meet its target of cutting emissions by 55% of 1990 levels by 2030, the EU must invest €813bn annually (or 5.1% of GDP) between 2024 and 2030; spending in 2022 was €407bn.[1419] Also in February 2024, Bloomberg New Energy Finance (BNEF) estimated that global investment in clean energy was $1.2 trillion in 2021, $1.5 trillion in 2022, and $1.8 trillion in 2023. This was around three times as much as investment in oil and gas. Investment in clean energy in 2023 was $670bn in China, $300bn in the US, $341bn in the EU and $74bn in the UK. The increase in renewable energy at around 800 gigawatts (GW) annually was greater than the 700 GW annual increase in power consumption. The International Energy Agency forecasts that fossil use in electricity generation will decline in 2024 in absolute terms and this will continue in future years. The introduction of sodium-ion batteries is estimated to reduce grid storage costs by two thirds to $40 kWh by 2026. Goldman Sachs has estimated that the 2022 US Inflation Reduction Act (IRA) prompted $282bn clean-tech projects in the first year and will ultimately total $3trn.[1420] Yet in the midst of this positive news, a study in *Science Advances* warns that the 'Atlantic meridional overturning circulation' (AMOC)[1421] could be close to a tipping point as a result of Greenland ice melt diluting seawater salinity and weakening the Gulf Stream which brings warm wet weather to North West Europe. A collapse in AMOC could reduce precipitation and lower average

[1414] https://www.greenclimate.fund/
[1415] https://www.thegef.org/what-we-do/topics/least-developed-countries-fund-ldcf
[1416] https://www.thegef.org/what-we-do/topics/special-climate-change-fund-sccf
[1417] https://www.adaptation-fund.org/
[1418] https://www.greens-efa.eu/en/article/study/road-to-net-zero; http://extranet.greens-efa.eu/public/media/file/1/8692; http://extranet.greens-efa.eu/public/media/file/1/8693
[1419] *Financial Times Newsletters*, 21 February 2024.
[1420] Ambrose Evans-Pritchard (2024) 2024 is the year when the world's green juggernaut becomes unstoppable, *Daily Telegraph*, 13 February.
[1421] AMOC or Gulf Stream comprises the northward surface-level flow of warm salty water and the deep-level southward flow of colder water.

temperatures in NW European cities by 5 to 15°C. There could also be a global chain-reaction which destabilizes rainforests.[1422]

The activities and pressures on institutional investors and banks is beginning to impact corporates themselves according to the 2024 ESG Risk & ROI Survey of chief financial officers released by accountants BDO. Of 600 CFOs questioned, 53% had embedded or were actively integrating sustainability into their core business strategy. BDO said CFOs 'have embedded sustainability and ESG factors into their overall operating and growth plans – to the benefit of their businesses, workers, stakeholders, and the environment. Driving sustainable value is a long-term game, but companies are also seeing immediate impact on their talent pipeline and workplace culture'.[1423]

In February, the Japanese government started issuing transition bonds for its Green Transformation (GX) programme. This aims to raise JPY150trn ($1trn) for advancing sustainable technologies over the next decade.[1424]

In 2024, the Just Transition Finance Lab was established at the LSE's Grantham Institute. Its executive director, Nick Robins, believes that institutional investors have a vital role to play: 'They remain key actors in signalling to the rest of the financial system the importance of climate action delivered through a just transition. More than this, pension funds are also pools of workers' capital, often with union and employee representation in their governance, bringing a direct link to the just transition agenda. …[However, there are] four main barriers – the lack of traction in financial decision-making, uncertainty about what good looks like, a lack of rules and incentives and insufficient leadership. The Lab's four objectives are designed to respond to each of these pain points, and our focus on financial instruments is starting with the bond and fixed income markets. [We have] partnered with the Climate Bonds Initiative to drive a more inclusive transition to net zero. The bond market has been one of the most impressive arenas for sustainable finance – green, social, sustainable and sustainably-linked – and Climate Bonds are a very effective market player with high integrity. …A transformation of the nearly $500trn global financial system is needed to bring the just transition to life'.[1425]

According to Sandor Steverink, senior investment consultant at WTW in the Netherlands, Dutch pension funds have been analyzing the just transition in the context of the UN SDGs: '[They] have embraced the Sustainable Development Goals. These are part of the Paris Agreement on climate change which includes just transition as an important principle. ….[However], the pension funds are becoming more selective in the SDGs that they are focused on. …Only a limited number of these SDGs are investable, of which SDG 7 'affordable and clean energy' and SDG 10 'sustainable cities and communities' are the most concrete with the highest probability to meet the risk/return targets'.[1426]

---

[1422] René M. van Westen, Michael Kliphuis, and Henk A. Dijkstra (2024) 'Physics-based Early Warning Signal Shows that AMOC is on Tipping Course', *Science Advances*, 10(6);10.1126/sciadv.adk1189
[1423] https://www.pensionpolicyinternational.com/esg-increasingly-part-of-core-business-cfo-survey-finds/
[1424] https://emea.nikkoam.com/articles/2025/sustaining-the-future-march-2025
[1425] https://impact-investor.com/special-report-pension-funds-grapple-with-the-just-transition
[1426] https://impact-investor.com/special-report-pension-funds-grapple-with-the-just-transition

In April 2024, the UK Financial Conduct Authority published a consultation paper on extending the Sustainability Disclosure Requirements regime to the UK fund management industry which covers around 400 firms with £1.4trn of assets under management. They would be required to use four SDR investment labels for the portfolios they manage: Sustainability Focus, Sustainability Improvers, Sustainability Impact, and Sustainability Mixed Goals.[1427] This will mainly impact DC pension plan members who choose their own investments. Fund managers were required to decide whether to adopt one of four sustainability labels by April 2025. However, only 80 funds (with £34.5bn in assets) had chosen a label by this date, whereas 325 funds (with £280bn in assets) had not selected a label. More than 50% of labelled funds have chosen Focus, followed by Impact, Improvers, and Mixed Goals. Further, all labelled funds are actively managed, with global large-cap equity strategies dominating.[1428]

However, fund managers must meet strict guidelines to receive a label. For example, a focus fund can only invest in companies that support sustainability, such as solar, wind or hydrogen companies. As a result, many funds have revised their investment policy statements and dropped any mention of 'sustainable'. For example, Schroder British Opportunities Trust chose not to apply for a label and removed any mention of ESG from its investment policy. Fewer funds than expected applied for a label. Morningstar said the low take-up had 'surprised everyone', adding 'There's lower investment demand and also the environment and the anti-ESG sentiment coming from the US mean there is less appetite, despite the surveys saying that investors are interested in sustainability'. The FCA has acknowledged the slow uptake of labels under the Sustainability Disclosure Requirements (SDR) arguing that it is 'still early days for the regime. We recognise that changes to fund managers' investment approaches require significant effort and will take time to phase in. … We are now seeing more and more funds adopting the labels. We have always acknowledged that some firms might not want to use sustainability labels'. Nevertheless, withdrawals from ESG equity funds exceeded inflows for the first time in 2024, with around $48bn of net outflows. European ESG equity funds, which include UK funds, saw $1.6bn of net outflows in November in reaction to Donald Trump's pro-fossil fuel views.[1429]

In May, the UK Sustainable Investment and Finance Association (UKSIF)[1430] released a report which called for 'supportive policies and regulation' that could lead to a £100bn increase in sustainable investment. The UK's sustainable finance sector needed strengthening in three key areas: a 'clear and world-leading sustainability disclosure regime', which would include the adoption of International Sustainability Standards Board

[1427] https://www.professionaladviser.com/opinion/4205980/extending-sdr-regime-portfolio-management
[1428] https://corporate-adviser.com/sdr-fund-labelling-incomplete-as-deadline-passes/
[1429] https://www.telegraph.co.uk/business/2025/01/05/why-the-city-is-turning-its-back-on-green-investing-trump
[1430] UKSIF's mission is: empowering the financial services industry to move further and faster to ensure a sustainable and responsible financial system; supporting members in the transition to a sustainable future, as exemplified by Net Zero and UN Sustainable Development Goals; and advancing the UK and our members in their leadership on sustainable and responsible finance and the integration of sustainability into all strategies and decision-making; https://uksif.org/

standards, the introduction of mandatory corporate transition plans and a UK Green Taxonomy, specifying the criteria for investments to be considered sustainable; clarifying the fiduciary duties of pension scheme trustees to enable them to factor in financially material ESG issues and manage associated risks and impact; and embed biodiversity into the regulatory framework.[1431]

Portfolio managers have been responding to proposals like this to design climate-aware multi-asset portfolios. One example is Wellington Management which has developed a framework for integrating climate change and its capital-market effects into multi-asset portfolios, thereby enabling asset owners to incorporate climate objectives into their portfolios via the strategic asset allocation (SAA).[1432] The framework consists of three pillars. The first focuses on incorporating climate-related inputs (including transition risks and physical risks) into the capital market assumptions (CMAs) underlying SAA decisions. The second is a climate-aware SAA approach, which adds relevant climate metrics to the asset allocation optimization process. The third pillar is implementation which involves selecting the specific climate-aware building blocks and strategies to meet the desired asset allocation.

In July, the Investment Delivery Forum (ID Forum), representing the UK's long-term saving industry, released an action plan to generate more private investment in support of public infrastructure spending from the UK's new National Wealth Fund (set up by the Labour Government elected on 4 July 2024). Insurance and pensions companies wanted the new government to make greater use of blended finance to attract the long-term private investment needed to help fund costly low carbon and other green infrastructure, such as electric vehicle charging networks, nuclear power development, floating offshore wind, carbon capture technology, and green hydrogen. In particular, they wanted public support from the National Wealth Fund to help mitigate the early-stage risks of investment in new infrastructure that private investors are currently unable to make due to regulatory rules designed to protect policyholders. Over the next 10 years, the UK's long-term savings industry has committed to channelling £100bn into 'productive assets', defined as those contributing to the real economy, expanding productive capacity, speeding up the energy transition or furthering sustainable growth. The plan would also track and report on investments made under the Solvency UK regulatory regime from January 2025. The ID Forum comprises seven insurance and long-term savings companies with an interest in large-scale infrastructure investment: Aviva, Just, Lloyds Banking Group, M&G, Phoenix, Rothesay and Royal London.[1433]

In September, a study from the University of Zurich and Dutch asset manager Robeco found that companies with a higher alignment to the United Nations Sustainable Development Goals were less likely to become embroiled in scandals. The study argued

[1431] https://www.portfolio-institutional.co.uk/esg-hub/uksif-unveils-proposals-for-regulators-to-boost-sustainable-investment/
[1432] A blueprint for building climate-aware multi-asset portfolios, Wellington Management, March 2024; https://www.wellington.com/en/insights/climate-aware-multi-asset-portfolios
[1433] https://impact-investor.com/insurers-outline-blended-finance-plan-for-uk-infrastructure/

that ‘This is imperative for investors: corporate scandals adversely affect market value and often have negative societal and environmental impacts. Aligning investments with the SDGs thus enables investors to enhance their financial and sustainability objectives’.[1434]

In October, the cumulative issuance of Green, Social, and Sustainability (GSS) bonds exceeded $5trn, according to ESG data provider MainStreet Partners.[1435] In the same month, Italian insurer Generali announced that it would no longer provide insurance for risks associated with oil and gas expansion, including new liquified natural gas (LNG) terminals and gas-fired power plants.[1436]

In October, it was announced that China had reduced particulate air pollution by 41% between 2013 and 2022, adding an estimated two years to national life expectancy. Beijing province experienced the largest decline in pollution, dropping 54.1% over the period.[1437]

In November, in a speech at the Mansion House in London, the UK finance minister, Rachel Reeves, announced the creation of a Transition Finance Council as recommended by the Transition Finance Market Review.[1438] She also gave the Bank of England a mandate to support sustainable finance and updated the remit letters of key regulators and supervisory committees to refer to the need for investment in the green transition. In addition, there were proposals for strengthening the voluntary markets for carbon and nature credits. Pension funds will be expected to show how their assets are being aligned with net zero, in addition to protecting the fund’s financial returns from climate change.[1439]

In December, the UK Land, Nature and Adapted Systems (LNAS) Advisory Group (a spin off from the Green Technical Advisory Group (GTAG)) published a report (Framework to Develop a UK Green Taxonomy for Adaptation and Resilience) which provides guidance on how to define a taxonomy to help the UK economy adapt to climate change. It outlined a five-step framework to define adaptation and resilience, and to encourage the mobilisation of capital into adaptation investments. The report stated: ‘As climate change impacts intensify, the UK faces escalating risks across all sectors of its economy. While building a net-zero economy remains crucial, adaptation and resilience must be elevated to be a parallel priority. Yet, adaptation investment continues to lag and current financial frameworks are not mobilising capital at the scale needed. …Green taxonomies have become useful tools for directing capital towards environmentally sustainable economic activities. However, their primary focus on mitigation to date has left the adaptation opportunity underdeveloped’. LNAS had previously published a report in October

[1434] https://impact-investor.com/report-sdg-alignment-reduces-risk-of-future-scandals/
[1435] https://funds-europe.com/green-bonds-drive-gss-bond-issuance-past-5tn
[1436] *Insurance Asset Management*, 23 October 2024.
[1437] https://epic.uchicago.edu/insights/chinas-air-quality-policies-have-swiftly-reduced-pollution-improved-life-expectancy/
[1438] https://www.gov.uk/government/publications/transition-finance-market-review
[1439] https://www.ipe.com/analysis/what-the-mansion-house-speech-means-for-green-finance-in-the-uk/10126456.article

outlining how disclosures in relation to sustainable agriculture, fisheries, and aquaculture could be structured in a UK Green Taxonomy.[1440]

Concern was being expressed about the energy and water cooling usage by data centres. With the massive growth of artificial intelligence, the International Energy Agency has estimated that data centres' total electricity consumption could double from 2022 levels to 1,000TWh in 2026, equal to Japan's 2024 total level of electricity demand. Google became the first tech company to commission new nuclear power plants for its data centres. Data centres have been trying to reduce their power usage effectiveness (PUE) factor by investing in closed-loop water consumption and recycling systems.[1441]

Also in December, the Trustee Sustainability Working Group (TSWG) was launched with the aims of accelerating the implementation of good sustainability investment practice across the pensions industry and encouraging consultants and investment managers to consider the global financial risks from not transiting to a net-zero world quickly enough. The TSWG said that, while it believes pension regulation has helped to increase awareness of sustainability and climate change, there was now an 'over-emphasis on low level reporting' which had direct implications for the use of trustees' limited resources, especially for small and medium-size schemes. It also believed that much of the climate scenario modelling across the industry was not decision-useful, with the output often 'at variance with the science' and it wanted to encourage further work in this area.[1442] In addition, it suggested that innovation was needed to ensure the assets schemes are investing in, such as global index tracking funds, remain resilient.[1443]

In 2024, $910bn of green, social, and sustainability (GSS) bonds were issued globally, the highest volume in three years.[1444] However, 88 global climate-themed funds (which cover low carbon, climate transition, green bond, climate solutions and clean energy/tech mandates) closed in 2024, up from 52 in 2023 and 18 in 2022. Hortense Bioy, head of sustainable investing research at Morningstar Sustainalytics, said that the main reasons for these closures were poor performance of renewable energy stocks and 'greenwashing concerns, political uncertainty and a growing anti-ESG sentiment' which lowered investor appetite for climate-based products: 'Clean energy stocks have had a volatile ride over the past six years. There was a boom followed by a four-year burst. So, I would not say they are a safe investment bet'.[1445]

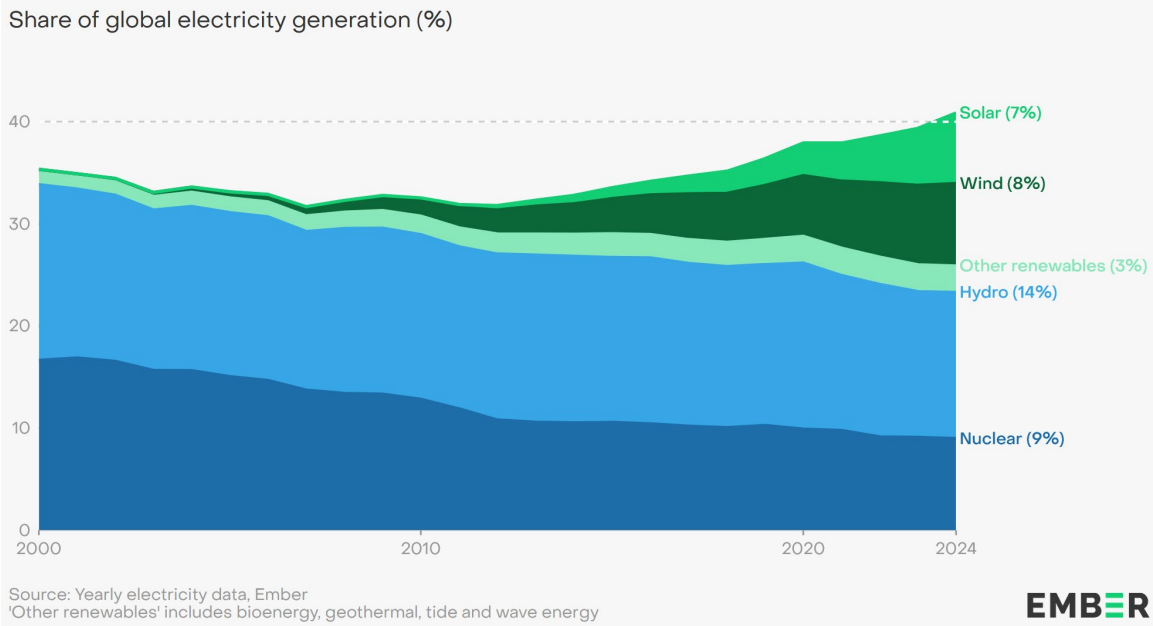
---

[1440] https://www.ipe.com/news/uk-government-advised-on-climate-adaptation-taxonomy/10127948.article
[1441] https://hub.ipe.com/asset-manager/pgim/greening-the-grid-data-centres-address-their-footprint/10076603.supplierarticle
[1442] https://www.professionalpensions.com/news/4387713/trustee-sustainability-group-launched-bid-accelerate-change
[1443] https://www.pensionpolicyinternational.com/uk-pension-trustees-urged-not-to-lose-sight-of-urgency-of-climate-issues/
[1444] MainStreet Partners, *Insurance Asset Management*, 6 February 2025.
[1445] https://www.investmentweek.co.uk/news-analysis/4409034/green-investors-ditch-worst-case-scenario-trump-amid-rising-climate-fund-closures

Article 9 (dark green) funds experienced net outflows in 2024, highlighting growing investor hesitation and sparking calls for a more accessible sustainable finance framework, according to European Fund and Asset Management Association (Efama) research. By contrast, Article 8 (light green) funds experienced net inflows in 2024, particularly in the money market and bond fund segments. Overall, their net assets held steady at around 51% of the total UCITS[1446] and alternative investment funds market.[1447]

In 2024, for the first time, more than 40% (40.9%) of global electricity generation was from clean sources, in particular from renewables and especially solar (which increased by 29% over 2023). However, heatwaves in 2024 caused an overall increase in electricity demand (by 4%) which resulted in a small increase in fossil generation, driving up power sector emissions to an all-time high – see Figure 16.[1448]

**Figure 16: Share of global electricity generation from clean sources, 2000-2024**




The World Economic Forum's *Top 10 Emerging Technologies of 2024* report identified a number of technologies that could provide solutions for overcoming climate change. One example is elastocalorics which aims to power heat systems to work like muscles, leading to more sustainable ways of keeping cool. Modern heat pumps use elastocaloric materials, such as nickel and titanium – which emit heat when mechanical stress is applied and cool down when the stress is relaxed – and are more energy-efficient than traditional heating and cooling systems and also avoid using environmentally harmful refrigerant gases. Another technology uses microorganisms which can capture greenhouse gases from air or

[1446] UCITS stands for 'Undertakings for Collective Investment in Transferable Securities'. These funds can be sold to EU retail investors and are subject to EU regulations.
[1447] https://funds-europe.com/article-9-funds-saw-net-outflows-in-2024-efama
[1448] https://ember-energy.org/latest-insights/global-electricity-review-2025/

exhaust gases and convert them into biofuels and protein-rich animal feed, which have the potential to reduce global warming.[1449]

**COP29 – November 2024**

In November 2024, COP29, the 29th United Nations Climate Change Conference, took place in Baku, Azerbaijan. The conference highlighted growing doubts about limiting global warming to 1.5°C, with 2024 set to breach 1.5°C for the first time and with the United Nations Environment Programme (UNEP) Emissions Gap Report, reflecting the slow progress in global climate action.[1450] A new deal was agreed for developed nations to provide $300bn annually by 2035 to help developing nations prepare for the impacts of climate change and transition away from fossil fuels, but this is less than the $1.3trn annually the UN estimates is required for a successful transition, implying that the private sector has to make up the shortfall.[1451] There was no progress on the commitment to reduce fossil fuel use, with discussions delayed until 2025; the 22-nation Arab Group would not accept any text in the deal which targeted specific sectors, including fossil fuels. There was a new agreement on a consistent mechanism for trading carbon credits internationally, with an accounting system for how a country selling a credit can deduct it from its national carbon inventory to prevent the same credit from being used twice. There was limited progress with the Loss and Damage Fund, established at COP27 to assist developing countries address emergencies such as sea-level rise, migration, reconstruction and recovery, such as the appointment of an Executive Director; to date, the total pledged financial support for the Fund exceeds $730m and is expected to start financing projects from 2025.[1452] There was the launch of the Harmoniya Climate Initiative for Farmers which aims to streamline the implementation of climate-agriculture projects, building climate-resilient agri-food systems through innovation and technology; there was particular focus on areas such as regenerative farming practices, precision strip-till farming, enhanced-efficiency fertilisers, and water-saving technologies. Around 30 nations, including 8 of the top 10 methane emitters, endorsed the Global Methane Pledge to reduce global methane emissions by 30% by 2030.[1453]

At COP29, the UN's Independent High Level Expert Group (IHLEG) on Climate Finance called for the direction of private finance towards emerging markets and developing countries (EMDCs) to meet net zero goals. It was set up at COP26 to assess net zero pledges from the private sector and other non-state entities. Its third report (Raising Ambition and Accelerating Delivery of Climate Finance) stated that: 'The transition to clean, low-carbon energy, urgently building resilience to the impacts of climate change, and protecting nature and biodiversity, requires a rapid step-up of investment in all countries. …This investment push will give a major boost to growth and development, and will lead to large, avoided

[1449] https://www.weforum.org/stories/2024/06/top-10-emerging-technologies-of-2024-impact-world/
[1450] https://www.unep.org/resources/emissions-gap-report-2024.
[1451] Some commentators have argued that this financing deal is 'too little, too late', see, e.g., Martin Wolf (2024) Climate change is a global problem – it requires a global solution, *Financial Times*, 27 November; https://www.ft.com/content/a0cfcf55-6b4d-4aeb-a3ec-b3db33575047
[1452] COP29_Investment_Briefing, XPS Group, November 2024.
[1453] https://funds-europe.com/cop29-climate-action-methane-pledge-agricultural-innovation

costs and very substantial savings. But this new growth story can only be realized through a major transformation of the climate finance system based on concerted efforts to unlock investment opportunities and ramp up all pools of finance'. The report also highlighted the need to tackle supply-side regulatory and incentive barriers to remove both legal and organizational constraints to investing in EMDCs, especially for clean energy and green industrialisation: 'While supply-side regulation like the prudential regime for insurance and reinsurance undertakings in the EU, Solvency II, is still a critical barrier to insurers, pension funds arguably do not have the same legal or fiduciary constraints'.[1454]

Also at COP29, the UK strengthened its climate commitments, by announcing a target 81% reduction in emissions by 2035. It also unveiled its 'Principles for Voluntary Carbon and Nature Market Integrity', establishing a framework to support high-integrity voluntary carbon markets (VCMs). The principles focus on using carbon credits to complement internal emission reductions, ensuring credit quality, transparent reporting, proactive planning, accurate environmental claims, and collaboration to build a trustworthy, efficient market. The principles aim to enhance market integrity by providing clear guidelines on claims transparency, biodiversity integration, and reporting standards. Mark Kenber, executive director of the Voluntary Carbon Markets Integrity Initiative (VCMI) said: 'The UK Government's principles align closely with the VCMI Claims Code, creating a robust framework for transparent and impactful carbon market participation… While these guidelines are essential, additional incentives will be crucial to encourage the private sector to confidently engage in carbon credits during this decisive decade'.[1455]

In December 2024, the Finnish-based Upright Project launched an impact database quantifying the impact of around 1,000 private equity and venture capital funds and 20,000 portfolio companies, having previously introduced a similar data base for 35,000 mutual funds and ETFs in September 2024. Upright used natural language processing technology to investigate 300 million scientific articles, databases from the World Health Organisation and the Organisation for Economic Co-operation and Development, and company disclosures in order to assess funds' environmental, social, health, and knowledge impacts globally. For general partners at PE/VC firms, the databases provide tools to benchmark impact performance, enhance portfolio management, communicate effectively with stakeholders, and future-proof value creation strategies. Mikael Homanen, head of scientific research, innovation and partnerships at Upright, said: 'It has [previously] been thought to be impossible to measure the impact of private equity because unlisted companies disclose little about their sustainability'.[1456]

Also in December 2024, the UK's Sustainability Disclosure Technical Advisory Committee (TAC) published recommendations on how global sustainability reporting standards should

[1454] https://www.ipe.com/news/un-expert-group-calls-for-major-financial-transformation-to-meet-climate-goals/10076864.article
[1455] https://funds-europe.com/cop29-uk-launches-carbon-market-integrity-priciples
[1456] https://funds-europe.com/worlds-first-private-equity-impact-database-goes-live

be incorporated into UK national law. TAC recommended adopting the International Sustainability Standards Board's first two standards, subject to amendments about reporting timeframes: International Financial Reporting Standard S1 (which explains how an entity should prepare and report its sustainability-related financial disclosures) and International Financial Reporting Standard S2 (which explains how climate-related disclosures should be reported). The ISSB wanted entities to disclose their Scope 1 and 2 emissions in the first year of adoption, with Scope 3 emissions and all other sustainability metrics to follow in the second year. TAC has recommended that sustainability metrics should wait until the third year. The ISSB also wanted investors and banks to use the Global Industry Classification Standard (GICS) for reporting sectoral categories, but TAC said any classification system should be permitted under UK law. The UK was one of the first countries to publicly declare support for the ISSB when it was set up in 2021.[1457]

**2025 developments in sustainability**

In January, a Texas federal judge ruled against American Airlines for prioritizing corporate and ESG interests over the financial interests of the participants in its DC pension plan in breach of its fiduciary obligations under the 1974 Employee Retirement Income Security Act. In a class action lawsuit, the judge has ordered both parties to demonstrate any direct connection between ESG investing and plan underperformance. The judge noted that 'BlackRock couched its ESG investing in language that superficially pledged allegiance to an economic interest. But BlackRock never gave more than lip service to show how its actions were actually economically advantageous to its clients'. BlackRock responded: 'We always act independently and with a singular focus on what is in the best financial interests of our clients. Our only agenda is maximizing returns for our clients, consistent with their choices'.[1458] The ESG court ruling prompted a coalition of 22 Republican state financial officials to demand that the Securities and Exchange Commission and Department of Labor implement stricter anti-ESG investing guidelines for asset managers and retirement plans. At the same time, T. Rowe Price research suggested waning enthusiasm for ESG among DC plan consultants.[1459]

In January, Donald Trump on becoming US President for the second time, signed an executive order withdrawing the US from the Paris climate accord. Some felt that this left a potentially huge void in global climate leadership, while others pointed to the success of global energy transition at the start of 2025. For example, the International Energy Agency's 2025 *World Energy Report* found that the decarbonisation market had doubled since 2018, exceeding $2trn annually which is twice the size of fossil fuel investments. Further, renewables deployment was 2.2 times higher in the years 2017-23 compared with 2010-16. In addition, there have been significant cost reductions across renewables: solar

[1457] https://www.ipe.com/news/uk-receives-official-advice-on-national-sustainability-reporting-standards/10127864.article
[1458] https://www.pionline.com/esg/federal-judge-rules-american-airlines-violated-erisa-esg-investments-401k-plans; https://environmentenergyleader.com/stories/texas-judge-rules-against-american-airlines-esg-retirement-plan-investments,61906
[1459] pionline, 31 January 2025.

photovoltaic costs have fallen by 90%, onshore wind by 70%, and batteries by more than 90%. Similarly, a US study by Greenwheel Research in January 2025 entitled *The Energy Transition under Trump 2.0* concluded that:[1460]

- Power demand growth is likely to drive deployment of grid infrastructure, gas power and renewables. Gas and renewables – particularly solar and onshore wind – are quick to build and economically attractive even without [federal] support.

- State-level policy may provide a significant backstop to rollback of federal support for clean technologies, particularly for renewables and battery storage, but potentially also for electric vehicles

- Further support for oil and gas production is not alone likely to stimulate growing output. Oil production is likely to be most significantly guided by international price dynamics. Growing domestic power demand and liquefied natural gas (LNG) exports are likely to boost US gas production in the coming years.

- Changes to US policy are not likely to materially alter the global trajectory for fossil fuel and clean technology production and demand, which are driven by wider dynamics and priorities.

Despite this, fossil fuels still supplied 80% of global energy demand and, for the first time ever, global warming rose to above the 1.5ºC target set by the Paris Agreement in 2024. China is emitting more carbon than all the developed nations (the US, Europe, Japan, Canada and Australia) combined. As a result, global warming will continue. The current path is off-trajectory for 2050 targets, while the Climate Action Tracker predicts a median temperature rise by 2100 of 2.7ºC on current policies. Aon's 2024 *Climate and Catastrophe Insights Report* indicated that global natural disasters in 2023 resulted in economic (including infrastructure) losses totalling $380bn. Earthquakes, flooding, severe convective storms and drought led to the biggest losses and significantly damaged both public and private infrastructure assets. However, insurance only covered 30% of losses, leaving a wide protection gap. Charlie Garrood, global head of infrastructure M&A and transaction solutions at Aon, said that 'understanding how resilient infrastructure assets are to potential climate scenarios prior to investing is becoming increasingly important. If an asset does not have adequate resiliency, adaptation measures can lead to additional capex spend, increased operating costs and changes to asset availability, all of which directly impact valuation'.

Francesco Dell'Alba, associate investment director at Cambridge Associates estimates that 'We need to invest $4.6trn per annum in clean energy by 2030, yet we're currently at about one-third of that amount. There are positives such as the growth of renewables…. and progress in electrification. However, you can only electrify about half of total energy

[1460] https://www.redwheel.com/uk/en/professional/insights/greenwheel-research-the-energy-transition-trump-2-0/#

requirements, and little has been made to reduce emissions in the other half. To close the gap, a lot more needs to be achieved within hard-to-abate sectors that cannot be electrified, where progress has been slower. Key alternatives for those sectors, such as green hydrogen and carbon capture, have yet to demonstrate proof of concept, with most projects facing delays. Investments in the grid are also lagging and the share of clean-energy investments in emerging markets is too low'. McKinsey & Company estimates that $275trn will need to be invested in physical and energy assets between 2021 and 2050 as part of the net zero transition. Over the same period, the demand for power will increase globally. Ulrik Fugmann, co-CIO and head of investment in the environmental strategies group at BNP Paribas Asset Management said: 'As power demand continues to go up, driven by electrification, reshoring and build-out of data centres to support the development of artificial intelligence, there is an increasing need for low-cost and reliable energy sources'. Despite these challenges, some observers are optimistic about the future. For example, Dan Wells, partner at Foresight Group said: 'Even though emissions are still increasing in absolute terms, the market forces at work are now unstoppable and are pushing us in the right direction'. [1461]

In January, the UK Sustainable Investment and Finance Association (UKSIF) recommended that the UK government incorporates the net zero transition in its growth plans: 'Long-term growth and sustainability are mutually reinforcing, given the material risks climate change poses to businesses across the UK and the huge opportunity the UK has to deliver the jobs and growth of the future as a leading sustainable economy'. This followed a speech by UK finance Rachel Reeves at the World Economic Forum in Davos saying that growth was the UK government's 'number one mission' and that this 'trumps' the government's net zero commitments.[1462]

In February, the UK Confederation of British Industry (CBI) published a study which found that the UK's net zero economy was growing three times faster than the overall economy: '[There has been a] 10.1% growth in the total economic value supported by the net zero economy since 2023. In 2024, there were 22,800 net zero businesses, with small and medium-sized enterprises (SMEs) making up 94% of the sector. Together, these businesses have pumped £28.8bn into the economy. …They also support 273,000 full-time jobs, outpacing employment in the telecommunications industry. …When you factor in supply chain activities, the sector's economic impact skyrockets to £83.1bn, supporting nearly 951,000 jobs across the UK – that's 2.9% of total UK employment. …Net zero jobs are 40% more productive than the national average, with wages 15% higher than the UK norm'.[1463]

In February, The People's Pension, the UK's largest master trust, withdrew £28bn from State Street, because it wanted to prioritize sustainability, active stewardship, and long-term value creation. The trust awarded a £20bn equity mandate to Amundi and £8bn in

[1461] https://realassets.ipe.com/analysis/energy-transition-the-state-of-play-as-trump-seeks-to-withdraw-from-paris-accord/10128310.article
[1462] https://www.ipe.com/news/uksif-urges-government-to-incorporate-net-zero-transition-into-growth-plans/10128398.article
[1463] https://www.cbi.org.uk/articles/growth-and-innovation-in-the-uk-s-net-zero-economy/

fixed-income assets to Invesco, both of which supported The People's Pension's commitment to responsible investment. This followed a retreat from ESG initiatives by US firms under the Trump administration.[1464]

In February, an Asset Owner Statement on Climate Stewardship was released urging asset managers to evolve and strengthen their climate stewardship strategies and highlighting the 'imperative' need for climate action. The statement aims to 'facilitate constructive conversations on climate stewardship and embed greater efficiencies into the stewardship chain, empowering asset manager stewardship teams to deliver on their asset owner climate objectives as part of their mandates'. It came from a group of 26 pension schemes from the UK, Europe, Australia and the US with assets of $1.5trn, including UK's Pension Protection Fund, The People's Pension, a number of UK Local Government Pension Scheme funds, Pensionskasse Basel-Stadt and SVVK-ASIR, a group of 11 Swiss pension and social security funds.[1465]

In February, the International Sustainability Standards Board released research suggesting that investors had a significant and growing interest in improved disclosures on human capital issues: 'Investors of all types operating in all jurisdictions have a strong interest in information on human capital-related risks and opportunities, primarily driven by a desire to manage investment risk and enhance returns'. It added the human capital project to its workplan, mirroring a parallel project on biodiversity and ecosystem services. The research has also revealed increased investor concern around workforce dynamics, such as technological disruption and demographic shifts, which could significantly reshape future disclosures. The workflow will 'evaluate the necessity and feasibility of potential standard-setting'.[1466]

In March, a report, published by the UK Sustainable Investment and Finance association (UKSIF) and Transition Risk Exeter (TREX) (*Stranding: Modelling the UK's exposure to at-risk fossil fuel assets*[1467]), estimated that £15.2bn (or 17% of a total of £88bn) in fossil fuel assets held by UK pension funds were at risk becoming stranded by 2040. The stranded assets relate to fossil fuel reserves which would lose economic viability before the end of their expected operational lifetimes due to climate policies, technological changes, or changing market conditions. This corresponds to 0.5% of the total of £3trn of UK pension assets. The report called for a clear regulatory framework to support sustainable finance and transition finance, including robust transition planning. It said that one of the essential components of an orderly transition would be a clear and credible regulatory framework to support sustainable finance and transition finance.

[1464] https://www.pensionpolicyinternational.com/uk-pension-fund-pulls-28bn-from-state-street-amid-esg-policy-divisions/
[1465] https://www.europeanpensions.net/ep/Asset-managers-urged-to-strengthen-climate-stewardship-strategies.php
[1466] https://www.ipe.com/news/issb-research-shows-growing-interest-on-human-capital-disclosure-demands/10129404.article
[1467] https://uksif.org/wp-content/uploads/2025/03/UKSIF-Stranded-Assets-Report-March-2025.pdf

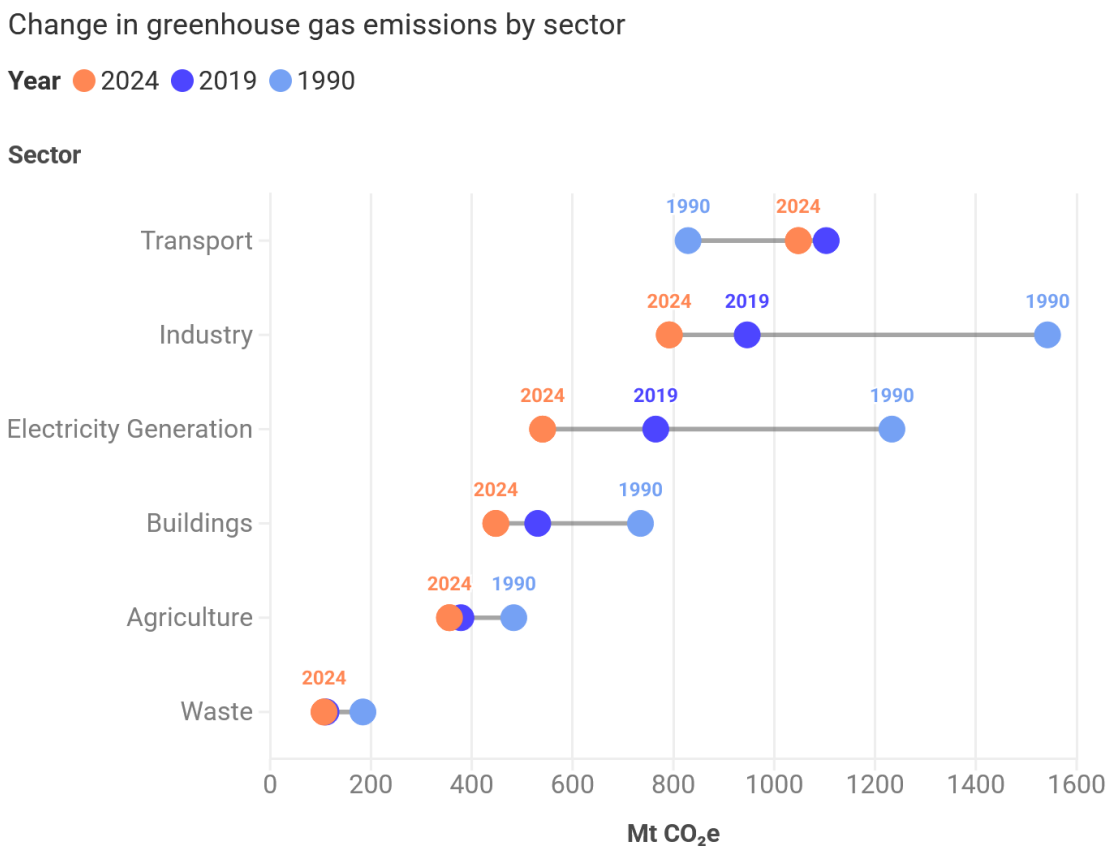
In March, the Financial Conduct Authority said its sustainability regulatory regime does not prevent investments in defence companies. This is in response to the UK and other European countries increasing military expenditure as a result of a reduced commitment by the US to European security following the election of President Trump. The regulations do not require financial institutions to treat defence companies any differently to other listed entities. They only have two main aims: 'to ensure information about investments claiming to be sustainable can be trusted and readily understood' and 'to improve the quality of sustainability-related information in the market'.[1468] Also in March, António Simões, the CEO of Legal & General, said UK military companies should be considered ethical investments because countries need to defend themselves: 'There's no reason in principle why investing in defence companies cannot be consistent with responsible investing. Governments should promote peaceful and inclusive societies but countries also may need to defend themselves. This is a UN-type of principle. We've always said that defence companies, including UK defence companies, can be invested in'. Some fund managers avoid businesses that manufacture weapons, as this is regarded as 'unethical'.[1469]

In March, Breakthrough Energy, the climate philanthropy organization founded by Bill Gates, announced that it was closing its policy and advocacy office. Gates conceded that global warming 'will not lead to humanity's demise'. He criticized the 'doomsday view of climate change' which focused 'too much on near-term emissions goals'. Instead, he called for a 'strategic pivot' in the effort against the climate crisis, with the emphasis shifting away from trying to limit rising temperatures in favor of efforts to prevent disease and poverty.[1470]

In March, a report released by Transport & Environment showed the success of the EU's Green Deal in terms of reducing transport emissions in Europe. Road transport emissions have decreased due to the increase in electric vehicles, but this has been partly offset by rising air travel – see Figure 17.[1471]

[1468] https://www.investmentweek.co.uk/news/4410684/fcas-sustainability-rules-prevent-investment-defence-companies
[1469] https://www.telegraph.co.uk/business/2025/03/12/city-must-back-defence-industry-to-protect-britain
[1470] https://heatmap.news/climate/breakthrough-energy-layoffs?next_url=%2Fclimate%2Fbreakthrough-energy-layoffs; https://www.theguardian.com/us-news/2025/oct/28/bill-gates-climate-crisis-pivot
[1471] https://www.transportenvironment.org/state-of-european-transport/state-of-transport-2025

**Figure 17: Change in greenhouse gas emissions by sector in Europe**




Source: UNFCCC, EEA, Stratas Advisors, Ember• Transport includes international aviation and maritime. Electricity Generation includes heat. 2024 values for Agriculture, Waste, Buildings, Industry are based on 5 year trends

T&E

In April, an academic study by Andrew Jackson and Tim Jackson (2025), by analysing the interactions between different industries, investment patterns and financial markets, provided evidence that a delayed and disorderly transition towards net zero emissions would threaten economic and financial stability, while increasing the economic risks and impacts from climate change. Under a disorderly transition scenario, fossil fuel firms that continue to invest in increased production would face huge stranded asset risks and costly write downs, which would, in turn, cause banks to increase interest rates on loans in an attempt to claw back lost capital. Higher interest rates would then create a vicious circle, making it harder for energy companies to raise capital to invest in a belated clean energy transition. There would also be a knock-on impact on the wider economy, with CPI inflation under an extremely disorderly transition scenario peaking at around 10% in 2030, before falling back to 5%.

By contrast, earlier shifts to reach net zero emissions are far more economically beneficial than delayed transitions that are likely to become more rapid and disorderly as governments and businesses seek to respond to escalating climate impacts during the second half of the

century. Under a more orderly transition scenario, inflation could rise in the short term as investment in the net zero transition ramps up, but in the medium to longer term investment expenditures would start to fall back to a level consistent with maintaining low carbon infrastructure capital stocks. That would then likely lead to lower inflation as economies become less exposed to energy price shocks.

The study concluded that targeted investments in green technologies, a robust financial framework to support these investments, and a clear and credible transition pathway can enable a smoother transition while safeguarding economic stability. Andrew Jackson said: 'Our work shows how delayed and disorderly transitions could ultimately lead to a combination of increased inflation, higher interest rates, economic stagnation and financial instability. Avoiding these transition risks, as well as the physical risks from climate change, requires that governments take concerted action now and do not delay action on the transition any further. By prioritising an orderly transition that is well signposted, governments can mitigate the risks associated with delayed and disorderly transitions. We need a re-evaluation of current transition strategies to advocate for an approach that considers the economic and financial costs from delaying the transition as well as the upfront costs of the transition itself. Only by taking a holistic view of all these costs can we pave the way for a sustainable future without jeopardising economic and financial stability'.[1472]

In April, an Aviva survey of 500 institutional investors found 60% considered sustainability to be a critical factor in private market investment assessments: 'The prime concern for majority of respondents (74%) was to prioritise financial returns with broad ESG integration, which demonstrates investors are not losing sight of the need to generate returns for clients. This matches a wider, global trend in impact investing, with 56% of investors globally seeking private market assets that achieve measurable ESG outcomes. …This trend reflects the growing appeal of investments that combine financial performance with positive societal and environmental impact, with increasing understanding of how these can fit into portfolios. …Larger companies tend to adopt more ambitious strategies, driven by their higher profiles and increased regulatory and stakeholder scrutiny. … When asked about decarbonisation plans, around half of respondents were still developing these for real estate, infrastructure and private corporate debt – with the percentages of actual implementation being only 29%, 27% and 15%, respectively'.[1473]

In April, researchers in China reported that the water hyacinth – a South American species that has colonized waterways around the world, by forming dense mats – was very effective

[1472] Andrew Jackson and Tim Jackson (2025) 'Macroeconomic, Sectoral and Financial Dynamics in Energy Transitions: A Stock-Flow Consistent, Input-Output Approach', *Ecological Economics*, 230: 108507, https://www.sciencedirect.com/science/article/pii/S092180092400404X; https://www.investmentweek.co.uk/news-analysis/4411151/economic-financial-instability-study-lays-bare-huge-risks-delaying-net-zero-goals

[1473] https://view.investmentweek.co.uk/aviva-investors-your-private-market-blueprint

at absorbing microplastics. In a controlled test, within 48 hours, the hyacinths had removed up to 69% of the polystyrene microplastic particles present; after five days, they removed as much as 78%. The plants were still healthy two weeks after the exposure. They can also remove agricultural runoff and heavy metals.[1474]

In April, the UK government established the Emerging Markets and Developing Economies (EMDE) Investor Taskforce, with the aim of raising private investment for tackling climate change and exploiting sustainable growth opportunities across emerging markets and developing economies. If successful, this could generate a tenfold return by 2100 and would increase the UK's financial and professional services sector's current £243bn economic contribution and £110bn in tax revenue, while also protecting and expanding its 2.4 million jobs. In addition, the taskforce will use practical solutions, such as capacity building and product innovation, to overcome hurdles that now hold back long-term private capital from climate, transition, and sustainable investment investments. These opportunities are present in regions including Latin America and the Caribbean, South and South East Asia, and Africa, according to the group. The EMDE Investor Taskforce comprises 15 financial services firms, as well as government expertise from HM Treasury and the Foreign, Commonwealth and Development Office. The firms include: Aviva Investors, HSBC, L&G, NEST, Ninety One, People's Pension, Pheonix Group, Private Infrastructure Development Group (PIDG), and S&P Global Ratings. According to the Institutional Investors Group on Climate Change, meeting global climate goals requires investment in mitigation and adaptation.[1475]

In May, Ocean Panel (The High Level Panel for a Sustainable Ocean Economy)[1476] (Ocean Panel), a global initiative of leaders from 18 countries, published a 'blue paper' (*The Future of the Workforce in a Sustainable Ocean Economy*[1477]) in partnership with its secretariat, the World Resources Institute (WRI). The paper highlighted the challenges and opportunities for employment and economic growth in the transition to a sustainable blue economy by 2050. The report found that the formal ocean economy employed around 133 million people globally and with the right support in place that figure could grow by 51 million by 2050 to 184 million, an increase of 1.5% per year from a 2019 baseline. It also examined opportunities for action, including through the deployment of funding mechanisms, such as green and blue bonds and impact investing. Tom Pickerell, global director of the ocean programme at the WRI, said that investment in the ocean economy has lagged investment elsewhere and that this needed to change: 'When it comes to the ocean economy, …we have not given it enough focus. Only 0.1% of funding channelled to the UN's SDGs goes to SDG14-Life below water. Investment is absolutely critical for so many different reasons, not least that over three billion people rely on blue foods for their survival. In terms of jobs, our report also found that there are possibly more than 250

[1474] https://humanprogress.org/invasive-water-hyacinths-are-effective-at-removing-microplastics/
[1475] https://www.investmentweek.co.uk/news/4413707/uk-government-financial-heavyweights-launch-global-taskforce-economic-growth-climate-changeg
[1476] https://oceanpanel.org/
[1477] https://oceanpanel.org/publication/ocean-employment/

million people, including informal and subsistence workers, in the ocean economy but we need better data'. The report identified seven key drivers of workforce change, such as climate change which will significantly affect employment in ocean economy sectors through changes to the abundance and distribution of fish stocks, increasing sea-level rise, the intensity and frequency of extreme weather events and algal blooms, and investment in offshore wind, tidal and solar energy projects. Pickerell said: 'There are climate-related biochemical reasons for investing in oceans and the ocean workforce. The oceans are responsible for 50% of oxygen produced on the Earth. It is also the biggest carbon sink in the world. So, we need to actively be managing the ocean and see it as an ally in the fight against climate change. Ocean-based climate solutions, such as wind power, blue foods or green carbon dioxide removal can contribute to about 30% of the emissions gap needed to maintain us on that 1.5ºC trajectory'. He added: 'There are three main channels for mobilizing and aligning finance. There's direct climate development finance that needs to be directed towards ocean workforce transitions and then there are the banks and private investors, who have a role to play in funding inclusive training, infrastructure and job creation in the coastal regions of the world, particularly in the Global South. The third channel was through public funding. That would derisk blue workforce programmes that can actually provide support for underserved populations'.[1478]

In May, UK-based climate intelligence firm Carbon Responsible reported that traditional methods of estimating corporate carbon emissions were highly unreliable when it came to Scope 3 emissions.[1479] Their research showed that commonly used Environmentally Extended Input Output (EEIO) models[1480] could overstate Scope 3 emissions by as much as 2,480% compared to verified emissions data from a sample of FTSE 100 companies. By contrast, Carbon Responsible's AI-powered emissions engine (Ada) reduced inaccuracies to just 80%, achieving a 97% improvement in precision. The company said: 'This represents a step-change in emissions measurement capability. When you're 97% more accurate than the industry standard, you're no longer in the realm of estimation – you're capturing investment-grade data'. The EU's Corporate Sustainability Reporting Directive (CSRD) and the US SEC's climate rule both now require the use of auditable emissions data, rather than the outdated approaches currently used by EEIO models.[1481]

In May, the UK's Pensions for Purpose and Impact Investing Institute released updated Impact Investing Principles for the UK pensions industry.[1482] The updated principles encourage pension schemes to set impact goals that represent the needs and values of their beneficiaries, such as housing, climate change mitigation or community wellbeing. The new framework also aims to establish stronger accountability by linking impact priorities with incentives and clearer reporting, encouraging schemes to focus on outcomes, rather

[1478] https://impact-investor.com/sustainable-ocean-economy-could-create-51-million-jobs-by-2050-report-finds
[1479] That is, indirect emissions, namely greenhouse gas emissions from a company's activities that are not directly owned or controlled by the company. They can come from supply chains, investments and product usage, and can account for over 80% of a company's total carbon footprint.
[1480] They rely on spend-based historic data that can be unreliable.
[1481] https://funds-europe.com/scope-3-emissions-overestimated-by-2480-ai-study-finds/
[1482] The first set of principles were drawn up in 2020.

than just intentions. Some of the revisions reflect changing legal views of fiduciary duty, which mean that beneficiaries in the UK can now reasonably expect their pension schemes to consider how investments will impact the social and environmental conditions prevailing in future at the point when they retire. The principles have been adopted by Aon MasterTrust, the Environment Agency Pension Fund, Smart Pension Master Trust, South Yorkshire Pensions Authority, Surrey Pension Fund and Wiltshire Pension Fund, among others. Investment consultant and fiduciary managers adopting the principles include Aon, Cardano, Redington, Schroders Solutions and XPS Investment. Supporters promoting the principles include GSG, the World Benchmarking Alliance and others. The have also been endorsed by the Global Impact Investing Network which oversees the global Operating Principles for Impact Management (OPIM).[1483]

In May, the US Department of Justice and Federal Trade Commission filed a statement of interest supporting a complaint made in November 2024 by the Texas Attorney General which alleges that BlackRock, Vanguard and State Street conspired to suppress the US coal market, by using their holdings in US coal companies to pressure those companies to adopt environmental, social and governance targets. The complaint highlights the managers' membership of organizations like Climate Action 100+ and the Net Zero Asset Managers Initiative, which both called for achieving net-zero investment portfolios. US Assistant Attorney General Abigail A. Slater said President Trump 'has declared a national energy emergency, and we need competition in coal production now more than ever to help fuel American energy dominance'. The three asset managers claim that they were acting lawfully.[1484]

In June, Schroders published its first *Group Nature Report* based on the government-recommended Taskforce on Nature-related Disclosures (TNFD). While such reports are now mandatory for many types of companies, they are voluntary for asset managers and asset owners, such as pension providers, and help them identify potential nature-related risks and opportunities. Schroders says the report underscores the firm's commitment to actively navigating nature risks and meeting clients' investment expectations in this space. The report follows the launch of Schroders' proprietary tool, NatCapEx, earlier in the year, which supports nature-focused, TNFD-aligned analysis across 9,000 public companies, building on Schroders' SustainEx model. Schroders global head of sustainable investment Andy Howard said: 'As a active asset manager, we are leading by example proactively disclosing our nature-related risks and opportunities, as well as developing our new proprietary tool, NatCapEx, to help fill the nature data gap. With the world's natural environments under growing pressure, measuring and managing the nature-exposed risks of our investments is becoming increasingly important. We also hope this voluntary disclosure in line with TNFD will help galvanise broader progress in corporate and investment disclosures. We will continue to engage with companies to encourage them to

[1483] https://impact-investor.com/revised-impact-investing-principles-for-uk-pension-schemes-launched/
[1484] https://www.ai-cio.com/news/doj-ftc-side-against-largest-asset-managers-in-esg-related-coal-suit

publish their own nature-related disclosures and shed light on this increasingly important risk and opportunity'.[1485]

In June, Phenix Capital published its 2025 Net Zero report which found that there had been no growth in the percentage of funds aligned with net-zero targets since the previous year (33% of the total). Reasons for this included wavering support for net zero by some of the world's largest asset managers and the challenges created by president Trump's decision to take the US out of the Paris climate change agreement for the second time. From an investor perspective, a lack of high-quality data and uncertainty regarding future government policies around the world were regarded as significant global challenges. Continuing controversy over some aspects of net zero targets, including concerns over their effectiveness, possible economic and social side effects and differing views on how best to achieve them created further uncertainties. Defining whether net zero goals should relate to carbon emissions or all greenhouse gas emissions added another layer of complexity to fund managers' decision making. Geographically, Europe accounted for the largest share of impact funds with net-zero targets (40.6%), followed by global funds (30.8%) and North America (27.3%). Just 11.2% of the net-zero aligned impact funds focused on Asia, including China and India. Some of the funds targeted more than one region. In terms of UN sustainable development goals, net-zero aligned funds focused principally on affordable and clean energy (SDG7), followed by climate action (SDG13), responsible consumption and production (SDG12) and industry, innovation and infrastructure (SDG9).

The report also highlighted the leading role being played in net-zero investing by pensions schemes, whose fiduciary duty increasingly includes the need to take account of climate risk on the investments – and lives – of their beneficiaries. Pension funds are the largest category of investors in net-zero aligned impact funds (282), followed by foundations (223) and development finance institutions (192). In the UK, schemes with over £1bn in assets under management are required to consider their exposure to climate risk to comply the Taskforce on Climate-related Financial Disclosures' standards. One of these, the London Pensions Fund Authority committed to investing around £250m in environmental solutions assets to support its net zero ambitions, while Wiltshire Pension Fund has a net-zero goal for its investment portfolio by 2050 and has published its first climate and nature report describing how it plans to do it.[1486]

In June, the Principles for Responsible Investment's Advance initiative announced that it was developing a strategy to help investors engage with policymakers on human rights issues. The initiative's 118 signatory investors uphold the UN's Guiding Principles on Business and Human Rights and engage with their portfolio companies to promote responsible business conduct. Members include Cardano, Phoenix Group and BNP Paribas which have developed case studies of human rights stewardship.[1487]

[1485] https://corporate-adviser.com/schroders-publishes-first-tfnd-report/
[1486] https://impact-investor.com/net-zero-drive-among-impact-funds-loses-steam-report/
[1487] https://www.ipe.com/news/pri-to-step-up-on-human-rights-lobbying/10130999.article

In June, the World Resources Institute (WRI) has published a study demonstrating that funding for climate adaptation and resilience was among the most impactful development investments available, with every $1 invested in climate adaptation and resilience generating a yield of more than $10 in benefits over a 10-year period. The study analyzed 320 adaptation and resilience investments totaling $133bn across 12 countries, between 2014 and 2024, and found that this translated to potential returns of over $1.4trn, with average returns of 27%. Examples included infrastructure built to better manage extreme weather events, irrigation systems that support diverse cropping patterns, evacuation centers that can double as community hubs, and nature-based solutions, such as watershed, wetland and coastal protections, which also provided recreational benefits. The investments were funded by multilateral development banks and international climate finance institutions [1488]

In June, Sierra Club Foundation announced that it terminated BlackRock's asset management contract for its $167m fund for failing to address the 'financial implications of the climate crisis' in its investments by promoting 'a dangerous all-of-the-above energy strategy' that accelerates climate change and harms clients' financial investments.[1489]

In June, EDHEC Business School's Climate Institute announced the creation of Scientific Climate Ratings (SCR), the first European rating agency dedicated to quantifying the financial materiality of climate-related risks. The ratings combine climate science, geospatial data, and financial valuation models. Covering around 6,000 infrastructure assets, SCR provides forward-looking ratings designed to inform investment, regulatory, and policy decisions. SCR offers two distinct but complementary outputs (see Figure 18):

- Climate Exposure Rating (CER), assessing the degree of exposure to future climate risk under a 'continuity' scenario – a projection based on current global policies and emissions trends. CER uses a transparent A–G rating scale.[1490]
- Climate Risk Rating (CRR), estimating the financial impact of climate risks in Net Asset Value terms, through both 2035 and 2050, using multiple scenario pathways weighted by probability. These are also rated on an A–G scale.[1491]

[1488] https://impact-investor.com/wri-study-reveals-ten-fold-impact-of-climate-adaptation-and-resilience-investments

[1489] P&I Daily, 26 June 2025.

[1490] The Climate Exposure Rating (CER):

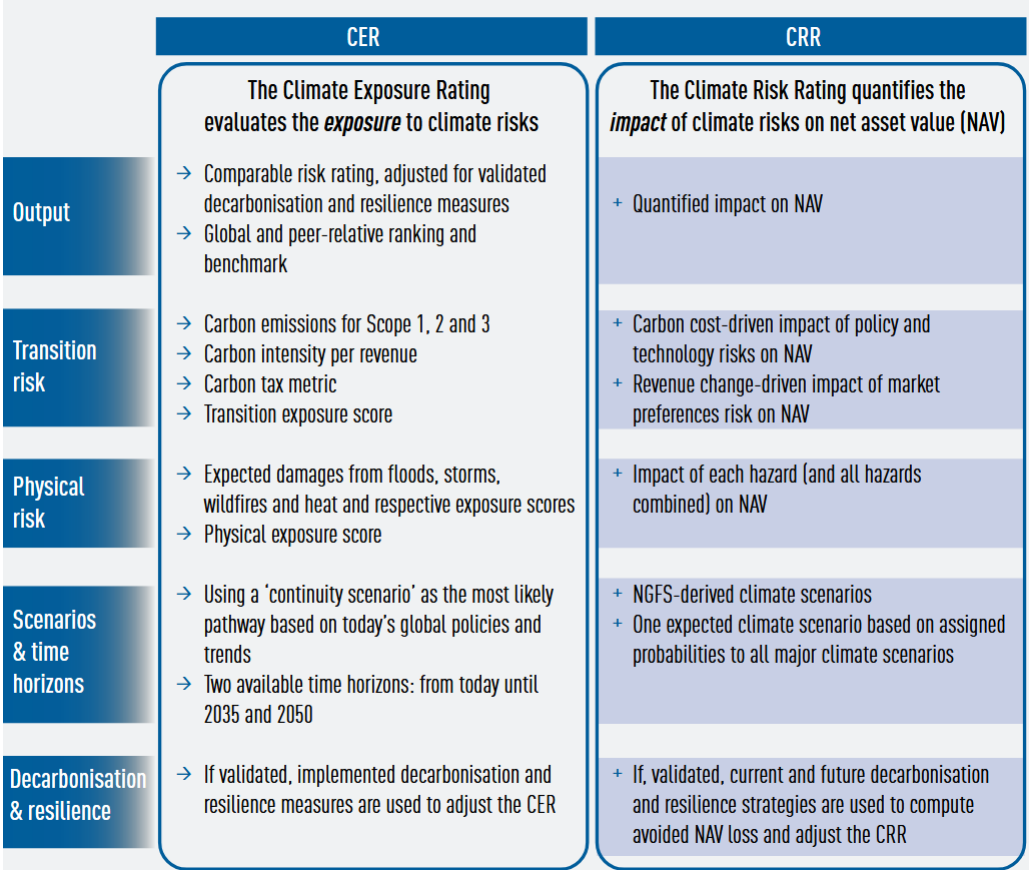
- Measures future climate exposure under a 'continuity' policy scenario, through 2035 and 2050. CER ratings are presented on a scale from A (low exposure) to G (high exposure), allowing for clear peer comparison.
- Computes Scope 1, 2 and 3 emissions to measure transition risk exposure accurately.
- Uses precise geolocation and asset boundaries to evaluate physical risk exposure.
- Accounts for adaptation efforts and their effectiveness, leveraging the comprehensive ClimaTech database.
- Translates the final exposure into a score and a rating designed for peer comparison.

Source: https://scientificratings.com/wp-content/uploads/2025/11/scr_ipe_supplement_nov2025.pdf (p.5)

[1491] The Climate Risk Rating (CRR):

The methodology adjusts for asset or company-specific adaptation measures using insights from the Climate Institute's ClimaTech database. The database includes standardized decarbonization and resilience strategies along with their documented impacts on emissions and physical damage.[1492]

**Figure 18: Quantifying the financial impact of climate risk with CER and CRR**




Source: Scientific Climate Ratings; https://scientificratings.com/wp-content/uploads/2025/11/scr_ipe_supplement_nov2025.pdf (Figure 3, p.6)

In July, the European Securities and Markets Authority issued four principles that should underpin sustainability-related claims by market participants:

- Quantifies dollar impact expressed as net asset value (NAV), by weighting a range of probabilities assigned to climate scenarios, including both physical and transition pathways, through 2035 and 2050 (rated from A to G).
- Calculates expected impact due to transition risk by analysing carbon costs and revenue growth.
- Computes expected impact due to physical risk through detailed geolocation and asset boundaries.
- Expressed as NAV impact, reflecting effects on cash flow and overall valuation.
- Accounts for adaptation efforts and their effectiveness by utilising the ClimaTech database.
- Translating the final exposure score into the CRR for peer comparison.

Source: https://scientificratings.com/wp-content/uploads/2025/11/scr_ipe_supplement_nov2025.pdf (p.5)

[1492] EDHEC Climate Institute, 26 June 2025.

- Accurate: Provide a balanced and factual reflection of the entity or product's positive and negative sustainability characteristics.
- Accessible: Ensure claims are presented in a way that is understandable, but not overly simplified, and easily found by investors.
- Substantiated: Base claims on robust evidence and credible methodologies, with full disclosure of underlying assumptions or limitations.
- Up to Date: Keep claims current and promptly disclose any material changes or revisions to the sustainability profile.[1493]

In July, the European Commission published a revised set of rules for disclosure under the Taxonomy Regulation. There will be a 90% reduction in the number of data points financial institutions have to report against, implying that investors do not have to evaluate certain assets and activities which do not contribute significantly to the overall portfolio. They will also be allowed to delay detailed disclosures for two years.[1494]

In July, the UK government announced that it would not introduce a green taxonomy to deliver the green transition, but would instead focus on policies that industry indicated would have a greater impact by making the UK a global hub for green and transition finance activity.[1495]

In July, the Association of British Insurers released the first annual update of progress made by the UK insurance and long-term savings industry's Investment Delivery Forum.[1496] In 2024, the ID Forum pledged to invest £100 billion into assets which contribute to economic growth and the net zero transition over the following decade. The update revealed that in 2024, £10.9bn had been invested against annuity business directly into UK focused productive assets, including:

- £3.8 billion invested in real estate, helping to build affordable and social housing and student accommodation.
- £2.7 billion invested in utilities including energy and water supply.
- £1 billion invested in transport, supporting buses and ports.
- The remaining £3.4 billion was invested across a variety of sectors including manufacturing, construction, and human health and social work.

In July, the European Insurance and Occupational Pensions Authority (EIOPA) released a public statement on how (re)insurers in Europe were integrating climate change-related risks in their Own Risk and Solvency Assessment (ORSA). EIOPA's monitoring exercise followed its Opinion on the supervision of climate change risk scenarios in ORSA.[1497] The results of the monitoring exercise show that insurers have made important progress in

[1493] ESMA Releases Practical Guidance on Sustainability Claims and ESG Credentials
[1494] https://www.ipe.com/news/eus-sustainability-simplification-drive-continues-with-taxonomy-esrs-updates/10131573.article
[1495] https://www.ipe.com/news/uk-government-decides-against-green-taxonomy/10131631.article
[1496] https://www.abi.org.uk/news/news-articles/2025/7/10.9-billion-invested-in-uk-productive-assets/
[1497] https://www.eiopa.europa.eu/eiopa-issues-opinion-supervision-use-climate-change-risk-scenarios-orsa-2021-04-19_en

integrating climate change-related risks into their risk management frameworks. Most (re)insurers surveyed now include climate change risk assessments in their ORSAs, covering both physical and transition risks. They are also making greater use of scenario analysis to assess the potential financial impacts of these risks. In a growing number of cases, climate change assessments are linked to defined management actions and are being taken into account in strategic decision-making. The exercise has also highlighted important challenges, including significant variations in approaches across jurisdictions, limited availability of high-quality, reliable and granular data, and the difficulty of extending the time horizon of analyses beyond what is typical for ORSA.[1498]

In July, the Autonomy Institute published a study which predicted that climate-induced price increases ('climateflation') for everyday food items could increase food prices by a third by 2050 and push 1 million people into poverty. The study suggested that heatwaves and droughts could affect domestic food production and disrupt international supply chains which would result in higher shop prices. The UK imports almost half the food it consumes. Will Stronge, chief executive of the institute, said: 'Climateflation is no longer a distant risk; it's a present reality. We need to build real economic resilience – and that means rethinking what public service provision can and should provide in the face of climate disruption: from delivery of basic essentials to publicly funded diners and a national buffer stock'.[1499]

In July, the US Department of Energy published an official report entitled *A Critical Review of Impacts of Greenhouse Gas Emissions on the US Climate*.[1500] The report acknowledged a warming trend since the onset of the industrial era and accepted that human activity might have contributed to greenhouse gas pollution, but argued that, given the scale of natural variations, such attribution remains difficult to confirm. The report concluded that the only rational response is adaptation.

The key points from the report are:

- Global warming causes only negligible impact on the economy. The report found that carbon dioxide–induced global warming has a far smaller economic impact than generally assumed. This was acknowledged by the Intergovernmental Panel on Climate Change (IPCC) its Fifth Assessment Report (AR5, Chapter 10, p. 662): 'For most economic sectors, the impact of climate change will be small relative to the impacts of other drivers.... Changes in population, age, income, technology, relative prices... and many other aspects of socioeconomic development will have an impact on the supply and demand of economic goods and services that is large relative to the impact of climate change'. The report argues that aggressive

[1498] https://www.eiopa.europa.eu/eiopa-monitoring-exercise-marks-progress-integration-climate-change-considerations-insurers-risk-2025-07-23_en
[1499] https://www.theguardian.com/business/2025/jul/28/climateflation-could-push-up-uk-food-prices-by-more-than-a-third-by-2050-report-says
[1500] https://www.energy.gov/sites/default/files/2025-07/DOE_Critical_Review_of_Impacts_of_GHG_Emissions_on_the_US_Climate_July_2025.pdf

mitigation strategies, are more harmful than beneficial, as their costs far outweigh their impact on global climate. In particular, it argues that the destruction of the industrial base in order to fund the 'energy transition', as in Europe, is practically and economically counterproductive.

- Negligible effects of US $CO_2$ emissions. While the US is a major emitter of greenhouse gases, it accounts for only about 14% of anthropogenic $CO_2$ emissions. The report argues that even a drastic domestic reduction would have only a marginal effect on global atmospheric concentrations. Reaching net-zero emissions in the US, for instance, would barely affect global temperatures, especially as major emitters like China and India continue to increase their output. The report found that the direct impact of US emission cuts on the global climate was 'undetectable', with any measurable effects emerging only after long delays, thereby casting serious doubt on the sense of ambitious unilateral measures. Europe has a 6% share of global emissions.

- There is no trend of weather events becoming more extreme. The report found that historical US data show no statistically significant increase in the frequency or intensity of extreme weather events—hurricanes, tornadoes, floods, or droughts.

- Beneficial effects of $CO_2$. The report notes that higher $CO_2$ concentrations stimulate plant growth, drive global 'greening' and enhance agricultural productivity. It also notes that atmospheric $CO_2$ enrichment boosts photosynthesis, with satellite studies such as NASA's showing expanded vegetation cover, particularly in semi-arid regions including the Sahel, India, and parts of Asia. Global plant and crop vegetation has increased by roughly 15-20% since the start of the industrial era, largely due to $CO_2$ fertilization. This greening has slightly reduced ocean alkalinity, with mixed impacts on coral reefs – notably, the recent recovery of the Great Barrier Reef.

- Limitations of climate models. The report argues that global climate models appear to overestimate future warming due to extreme emission scenarios and exaggerated predictions of climate sensitivity. Estimates vary widely (from 1.8 °C to 5.7 °C for a doubling of $CO_2$). Models also tend to produce projections that are too 'hot' compared to recent observations. The report criticized the excessive use of the high-emissions 'RCP8.5' global warming scenario, which it argues lead to misleading projections, particularly regarding a rise in sea levels and its regional impact, and, in turn, to a literature that is 'imbalanced in an apocalyptic direction'.

- Scientific uncertainties. The report argues that attributing climate change and extreme weather to human $CO_2$ emissions remains overflowing with uncertainty, due to: natural climate variability, limitations in available data and gaps in climate modelling. To illustrate, lower stratospheric temperatures have shown no significant trend since 2000, contrary to model predictions of $CO_2$-driven cooling.

This suggests that natural factors, such as solar flares or volcanic events, may be more influential in certain climate patterns.

In August, the UK's Smart Pension agreed to invest £330 million in renewable energy, via funds managed by Octopus Energy Generation, the renewables investment arm of Octopus Energy. The aim is to support the UK's low-carbon transition, while generating long-term returns for members. One example is a ground source heat pump network bringing renewable heating and hot water to 114 new homes at Parc Eirin in South Wales.[1501]

In August, research from Isio indicated that just 39% of asset managers had adopted formal ESG objectives or focus areas, compared with 49% in the previous year. This was due to increased regulatory scrutiny, evolving labelling regimes, and a desire to avoid greenwashing claims. This contrasted to the headline data suggesting that 97% of asset managers had an established ESG policy and dedicated sustainability teams. Despite this, more firms were removing measures to check if goals were actually being achieved. Cadi Thomas, head of sustainable investment at Isio, said: 'There is still significant work to do at fund level. Disclosures remain inconsistent, particularly in private markets, and while climate reporting has improved, social and nature-related data continue to lag. Fewer funds are adopting formal ESG objectives, potentially driven by increasing labelling scrutiny'.[1502]

In August, the UK's NEST pension scheme invested $750m in sustainably managed timberland in the Americas via BTG Pactual Timberland Investment Group with the aim of achieving strong risk-adjusted returns.[1503]

In August, the UK Financial Conduct Authority reported the results of a climate reporting review of UK asset managers, life insurers and FCA-regulated pension providers.[1504] It found that its 2021 climate disclosure rules had increased firms' consideration of climate risks and supported their integration into firms' decision-making. Firms were more transparent with their clients and consumers but encountered some challenges with the availability of data and consistent, well-developed methodologies. Firms also considered some information too complex for retail investors to engage with and thought the regime could be less granular and more proportionate. They saw opportunities to simplify reporting, particularly given their broader sustainability disclosure obligations. In light of these findings, the FCA said it would consider how to streamline and enhance its sustainability reporting framework. It wanted to: simplify disclosure requirements and ease unnecessary burdens on firms; maintain good outcomes for clients and consumers and improve the decision-usefulness of reporting, building on the work of SDR to improve trust

[1501] https://funds-europe.com/smart-pension-invests-330mn-in-uk-clean-energy
[1502] https://www.investmentweek.co.uk/news/4517302/asset-managers-massively-pulling-concrete-esg-objectives-reporting-significant
[1503] https://realassets.ipe.com/news/uks-nest-commits-750m-to-americas-timberland-via-btg-pactual-tig/10132006.article
[1504] https://www.fca.org.uk/publications/multi-firm-reviews/climate-reporting-asset-managers-life-insurers-fca-regulated-pension-providers

and reduce greenwashing; and promote international alignment and help maintain the UK's position as a global leader in sustainable finance.

In September, the Lloyd's of London insurance market scrapped its net zero policies in response to President Donald Trump's attack on pro-green financing. Insurers operating at Lloyd's will no longer be required to stop insuring the most polluting fossil fuel projects by 2030 and become entirely net zero by 2050. Instead, insurers will only be expected to operate in line with the laws of countries in which they operate.[1505]

In September, real assets sustainability benchmark provider GRESB and the Institutional Investors Group on Climate Change released a new methodology for assessing how infrastructure assets align with the Net Zero Investment Framework (NZIF) 2.0. The framework provides 'a common language for sustainability' that enables consistent comparisons across assets. Eleven global investors and managers, including Aberdeen, Arcus Infrastructure Partners, CVC DIF, IFM Investors, JP Morgan, Macquarie, Morrison Global, Patrizia and PGGM, took part in the working group. A pilot study showed that 16% of respondents reported their assets already achieve net zero, 62% have committed to alignment but have not yet reached their targets, while 20% have yet to commit. Half of participants have set science-based targets. All respondents disclosed Scope 1 and 2 emissions, but under 50% disclosed all Scope 3 emissions. In addition, 84% had governance structures with responsibility for decarbonisation plans, and 42% reported a measurable decline in emissions.[1506]

In September, the European Court of Justice ruled in favour of the European Commission in two legal challenges over its definition of 'green' under the EU Taxonomy Regulation. Austria filed a legal challenge requesting that the delegated act that added nuclear and gas into the Taxonomy Regulation in 2022 at the request of Germany and France be annulled. In the second case, ClientEarth filed a case against the Commission for 'unlawfully labelling the burning of forest biomass to produce energy, and the manufacture of bio-based plastics and chemicals used to make plastics as "sustainable" in the EU taxonomy'. The ECJ court ruled that the Commission 'was entitled to take the view that nuclear energy generation has near to zero greenhouse gas emissions and that there are currently no technologically and economically feasible low-carbon alternatives at a sufficient scale. …The General Court endorses the view that economic activities in the nuclear energy and fossil gas sectors can, under certain conditions, contribute substantially to climate change mitigation and climate change adaptation'.[1507]

In September, Scotland's National Investment Bank announced that had put impact investing at the heart of its £2bn strategy, targeting the climate emergency, place-based

[1505] https://www.telegraph.co.uk/business/2025/09/04/lloyds-of-london-reverses-net-zero-ban
[1506] https://realassets.ipe.com/news/gresb-and-iigcc-join-forces-on-net-zero-alignment-for-infrastructure-assets/10132500.article
[1507] https://www.ipe.com/news/court-sides-with-european-commission-over-definition-of-green-business/10132560.article

inequality and demographic pressures, mainly driven by Scotland's ageing population. The three missions of the SNIB are: to address the climate crisis through growing a fair and sustainable economy; to transform communities, making them places where everyone thrives; and to scale up innovation and technology for a more competitive and productive economy. It has so far invested in 39 SMEs and five funds: Social and Sustainable Housing (SASH), Gresham House Forestry Fund, Thriving Investments MMR Fund, Par Equity, and Iona Wind Partnership. For every £1m it has invested by the SNIB, its investees have received on average a further £1.9m from other sources.[1508]

In September, a Morningstar proxy-season analysis revealed a 40% decline in ESG resolutions in 2025, with only 30 significant proposals garnering at least 30% shareholder support. This contrasts with the previous five years when US-listed companies faced more than 100 resolutions annually. Morningstar found that major asset managers remained hesitant to back ESG initiatives, with Vanguard Group abstaining from supporting any ESG proposals. The six largest US asset managers showed only modest engagement, with average support for significant ESG resolutions at 18% – up from 17% in 2024, but below the 46% peak observed in 2021.[1509]

In September, the European Environment Agency reported that the average annual economic losses in the EU associated with intense heat, floods and other extreme weather was €44.5bn between 2020 and 2023, two and a half times as high as between 2010 and 2019. It said that 75% of companies producing goods and services in the Eurozone are 'highly dependent' on at least one natural ecosystem, adding that 75% of bank loans are given to companies that rely on natural resources for their business and almost 15% of industrial assets are on floodplains. Europe is the fastest-warming continent and this is leading to increasingly volatile weather patterns together with an increase in forest fires and floods.[1510]

In September, ING, FTSE Russell and Robeco published a report entitled *Rethinking Sovereign Debt to Finance the Climate Transition: Introducing a novel investment solution*.[1511] The report pointed out that climate change mitigation and adaptation require substantial financial resources. Hence, governments might increasingly turn to financial markets to raise funding through sovereign bond issuances. This provided an opportunity for sovereign debt investors to finance the low-carbon transition and encourage governments to implement robust climate policies. ING, FTSE Russell and Robeco have developed an investment solution – involving an investable index intended to drive capital toward climate leaders – that offers institutional investors the following benefits: alignment with climate goals, such as climate change mitigation and adaptation; performance potential, since the index favors countries that are better managing climate-related challenges, potentially leading to improved economic performance and credit ratings; risk

[1508] https://impact-investor.com/impact-investing-central-to-scotlands-development-bank-strategy
[1509] pionline@e.crainalerts.com; 24 September 2025
[1510] https://www.ft.com/content/b119fd7e-0507-4b13-b839-80da8314ad7f
[1511] https://www.lseg.com/en/ftse-russell/research/rethinking-sovereign-debt-to-finance-the-climate-transition

management investing in countries with strong climate performance, thereby helping mitigate transition risks; and sovereign engagement opportunities.

In October, a federal judge in Fort Worth, Texas, issued a series of restrictions and requirements on fiduciaries of two American Airlines 401(k) plans to remove 'ESG influence' on investment management. He said plan fiduciaries violated ERISA's duty-of-loyalty provision, which says fiduciaries must put participants' interests ahead of corporate interests, by allowing nonpecuniary factors, such as ESG and sustainability, to influence investment management.[1512]

In October, PFZW, the Netherland's second-largest pension fund (with assets of €248bn) announced that BlackRock had lost its contract to manage its $17bn passive equities fund. This followed from PFZW's revised investment regime that emphasizes sustainability in equal measure with return and risk. There was also a pivot towards active management.[1513] In December, PME, another Dutch pension fund, withdraw its €5bn global ESG equity portfolio from BlackRock and transferred it to UBS Asset Management and MN.[1514]

In October, the Trump administration announced that it would open 13 million acres of federal lands for coal mining and provide $625m to recommission or modernize coal-fired power plants. This will help to meet rising US electricity demand from data centers, artificial intelligence and electric cars. At the same time, the government has reduced the growth of renewable energy by freezing permits for offshore wind projects, ending clean energy tax credits and cancelling wind and solar projects on federal lands. Interior Secretary Doug Burgum said that President Trump now had another initiative: 'mine, baby, mine'. Environmental groups denounced the actions. The Environmental Defense Fund said: 'Subsidizing coal means propping up dirty, uncompetitive plants from last century – and saddling families with their high costs and pollution. We need modern, affordable clean energy solutions to power a modern economy, but the Trump administration wants to drag us back to a 1950s electric grid'.[1515]

In October, the Global Tipping Points study reported that global warming was approaching critical thresholds sooner than expected, with coral reefs suffering what researchers describe as an almost irreversible decline, marking the first major climate tipping point. The study also warned that the Amazon rainforest could collapse if temperatures exceed 1.5°C and that key ocean currents are also at risk. With global temperatures already 1.3-1.4°C above preindustrial levels and the years 2023 and 2024 being the hottest on record, the 160 researchers involved in the study recommended stronger emissions cuts. The report was prepared for COP30 in Belém, Brazil between 10 - 21 November 2025. The world is currently on track for 3.1°C degrees of warming by the end of the century, based on national policies.[1516]

[1512] pionline@e.crainalerts.com, 2 October 2025
[1513] pionline@e.crainalerts.com, 2 October 2025
[1514] https://www.ipe.com/news/pme-replaces-blackrock-in-5bn-esg-equities-portfolio/10134286.article
[1515] https://abcnews.go.com/US/wireStory/trump-administration-opens-land-coal-mining-offers-625m-126048784
[1516] https://www.yahoo.com/news/articles/climate-tipping-points-being-crossed-182734510.html

In October, a proposal from the UN's International Maritime Organisation to impose a net-zero levy on ships of up to £360 per ton of $CO_2$ emitted over a certain level was delayed for a year after President Trump labelled the proposal a 'green scam'. He threatened to impose sanctions on countries that signed the agreement which would raise consumer prices by at least 10%.[1517]

In October, the UK Emissions Trading Scheme reported that 15% of the UK's reduction in greenhouse gas emissions since 2004 was explained by the closure of 116 energy-intensive factories such as steelworks at the cost of 30,000 jobs. Overall emissions fell by 65% since 2014 due in part to a fall in power generation from domestic industries.[1518]

In October, the European Investment Bank Group announced €10bn in annual financing from 2025 to 2027 for EIB Global, its international partnerships and development arm, to fund high-impact projects in more than 130 non-EU countries dealing with poverty, energy shortages, pollution, drought and extreme weather events.[1519]

In October, a study by Bloomberg reported that the financial markets were pricing physical climate risk (those relating to, e.g., tropical cyclones, heat stress and flooding) into firms' cost of capital, with firms with higher exposure to physical risks facing an approximate 22 basis point premium per 10 point increase in physical risk in their weighted average cost of capital (WACC) (with a 95% confidence interval of 12-31 bps). The pricing effect was found to be clearest within the materials and utilities sectors, which saw an average increase of approximately 56bps and 45bps WACC per 10 point increase in physical risk, respectively.[1520]

In October, the *Financial Times* reported that, having declined as a result of the growth of renewable energy, orders for gas turbines has been increasing since 2021, driven by the demand for electricity from the data centres that are powering the artificial intelligence revolution. AI-related computing capacity requires reliable 24-hour power. In 2024, the US Department of Energy forecast that data centres would consume 6.7 to 12% of US electricity by 2028, compared with 4.4% in 2023. The International Energy Agency predicted in April 2025 that data centres' electricity use globally would double by 2030 to 945 terawatt hours, more than Japan's current power consumption. Climate activists argue that this will breach the Paris climate agreement.[1521]

In October, the UK's £31.2bn Pension Protection Fund published its first sustainability report, covering its UK Stewardship Code submission to the Pensions Regulator, its climate change report that aligns with the Task Force for Climate-related Financial Disclosures

[1517] https://www.telegraph.co.uk/politics/2025/10/17/starmerglobal-net-zero-tax-tatters-us-revolt
[1518] https://www.telegraph.co.uk/business/2025/10/20/15pc-drop-carbon-emissions-caused-industrial-decline
[1519] https://impact-investor.com/eib-expands-investments-outside-eu-to-up-to-e10bn-a-year
[1520] https://www.ipe.com/news/physical-climate-risks-are-being-priced-into-cost-of-capital-finds-analysis/10133266.article
[1521] https://www.ft.com/content/dfd87d3d-a386-4706-a4ba-9f9274760111

(TCFD) recommendations, and reporting about sustainability at the PPF as an organization. Key achievements during the year included 'significant work to ensure potential external investment managers meet our expected standards and worked with several to develop their stewardship processes'. In private markets, the PPF was pushing for greater transparency, better data quality and more credible transition plans.[1522]

The Climate Financial Risk Forum (CFRF) 2025 Symposium was held in London in October.[1523] The UK's long-term growth prospects depended on maintaining its leadership in transition finance despite politics and global competition for green capital, according to a panel session entitled 'Investment Opportunities and the Future of Sustainable Finance' which included representatives from the UK Sustainable Investment and Finance Association, the Green Finance Institute, and the UK Transition Finance Council. Panel members suggested that UK must show leadership and give business and industry the confidence to continue on the course to net-zero, describing the challenge as one of unlocking economic opportunities rather than just managing climate risk. It also discussed how the UK government's Transition Finance Playbook aims to bridge the gap between financial planning, technology pathways and project delivery, ensuring that local projects have credible finance plans from the outset. However, despite frameworks, the flow of capital into transition projects remained below expectations. Policy inconsistency and a shortage of investable deals were the main bottlenecks, and investors need planning and grid-connection barriers cleared to accelerate deployment. The panel concluded that the UK's status as a global centre for sustainable finance should be measured not only by domestic investment, but also by how effectively it channels capital abroad: 'We have immense financial expertise within a few miles of the City. The real opportunity is to deploy that globally'.[1524]

The CFRF also published a number of studies to help financial markets integrate climate adaptation and scenario analysis into their decision-making. One piece of research involves nine case studies from companies like Aviva, Aberdeen Investments and Legal & General which examines different approaches to quantifying the financial impacts of climate scenarios. This will help investors benchmark themselves against peers, develop new use cases and methods, and support risk-based internal discussions. The CFRF also released an interactive tool – the Online Climate Scenario Narrative Tool – that generates a summary of investors' climate-related risks and opportunities, based on their business activities and products; it utilizes data from scenarios developed by the Central Banks' and Supervisors' Network for Greening the Financial System. In addition, the CFRF published recommendations on how to provide training and awareness in the financial markets about the physical risks posed by climate change.[1525]

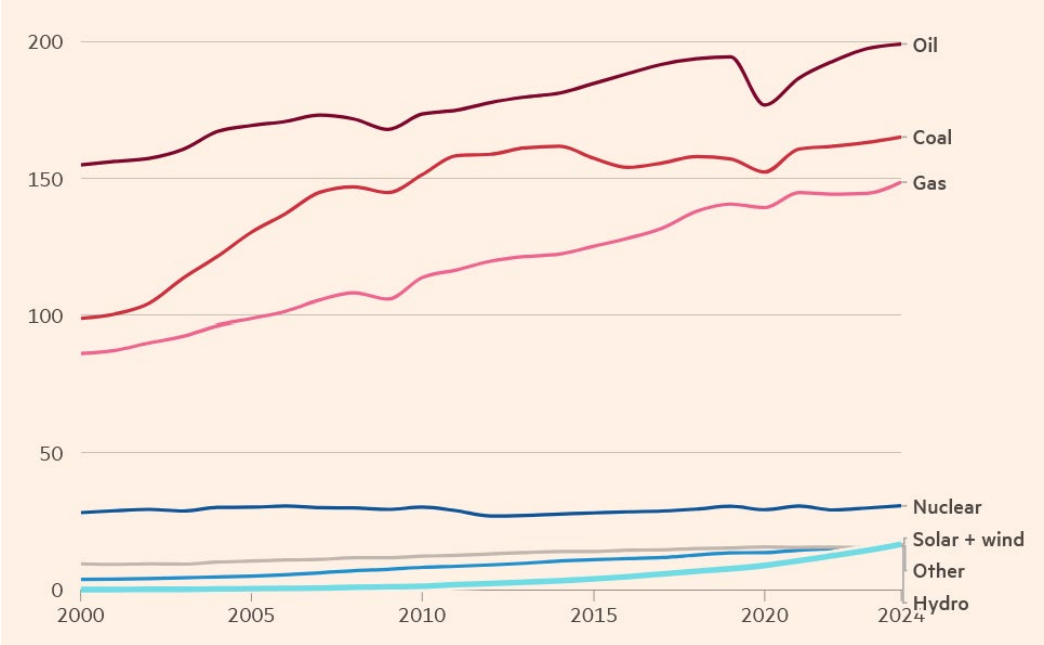
[1522] https://www.ipe.com/news/uks-ppf-publishes-first-sustainability-report/10133298.article
[1523] The Climate Financial Risk Forum was set up by the UK Financial Conduct Authority and the UK Prudential Regulation Authority in 2019.
[1524] https://funds-europe.com/transition-finance-seen-as-key-to-the-uks-green-growth/
[1525] https://www.ipe.com/news/uk-investors-regulators-address-climate-risks-in-new-reports/10133385.article

The UN Food and Agriculture Organization's *Global Forest Resources Assessment 2025* found that the rate of deforestation is slowing down. Between 2016 and 2025, the world lost 10.9 million hectares of forest annually, down from 13.6 million between 2000 and 2015, and 17.6 million between 1990 and 2000.[1526]

In October, the EDHEC Climate Institute reported that up to 54% of global infrastructure value is at risk from climate-induced weather events without adaptation. US$10bn in assets face devaluation risk due to non-alignment with sustainability criteria, and another US$245bn is exposed to regulatory uncertainty. Yet fewer than one-third of major infrastructure companies disclose credible transition or resilience strategies.

The Energy Institute's 2025 Statistical Review of World Energy reported that electricity generation from oil, gas and coal continued to rise, implying that renewables were still only helping to meet the increase in energy demand, rather than reducing fossil fuels – see Figure 19.

**Figure 19: Global energy supply, by fuel type (exajoules)**




Source: EI Statistical Review of World Energy, 2025; https://www.energyinst.org/statistical-review; https://assets.kpmg.com/content/dam/kpmg/sk/pdf/2025/Statistical-Review-of-World-Energy-2025.pdf; https://www.ft.com/content/c4068478-c091-4e87-a3cd-5bfc71281ec8

In October, Net Purpose acquired the Sustainable Development Investments Asset Owner Platform (SDI AOP), forming one of the largest independent providers of sustainable development data. The merged organization aims to create an advanced data infrastructure to help accelerate investing in climate and other UN Sustainable Development Goals and

[1526] https://openknowledge.fao.org/handle/20.500.14283/cd6709en

will serve clients with more than $40trn in assets. Net Purpose will integrate SDI AOP's methodology, data processing and customer services into its platform, and will launch SDG classifications under the unified framework, thereby 'aligning around common standards to achieve measurable impact', as investor demand shifts from box-ticking compliance to real-world outcomes.[1527]

In October, a report entitled *Roasting the Planet: Big meat and dairy's big emissions* was released by Foodrise, Friends of the Earth US, Greenpeace Nordic, and the Institute for Agriculture and Trade Policy.[1528] The report found that 45 large meat and dairy companies – including JBS, Marfrig, Tyson, Minerva, and Cargill – generated more than a billion tonnes ($CO_2$-equivalent) of greenhouse gas emissions in 2023 – more than the emissions of Saudi Arabia. Over half of emissions from the sector came from methane – generated from enteric fermentation and manure – more than that produced by all European countries. The report called for policies that set binding targets for agricultural GHG emissions cuts, reduced animal farming and the promotion of a shift to healthy, sustainable and plant-rich diets. The big meat and dairy companies responded by saying they were taking various steps to bring down emissions or tackle deforestation.[1529]

In October, the United Nations Environment Programme (UNEP) *Adaptation Gap Report 2025* estimated that the cost of adaptation finance needed in developing countries was $310bn per year in 2035, when based on modelled costs, and $365bn per year, when based on extrapolated needs expressed in Nationally Determined Contributions (NDCs) and National Adaptation Plans (NAPs). However, international public adaptation finance flows to developing countries were $28bn in 2022 and $26bn in 2023, implying that adaptation financing needs in developing countries are 12-14 times as much as current flows. The report added: 'If current finance trends continue, the Glasgow Climate Pact goal of doubling international public adaptation finance from 2019 levels by 2025 will not be achieved, while the New Collective Quantified Goal for climate finance is not ambitious enough to close the finance gap. The private sector could do more – with potential to provide around $50bn per year if backed by targeted policy action and blended finance solutions. While far from enough, there is visible progress on closing the planning and implementation gap. Most countries have at least one national adaptation policy, strategy or plan in place; countries are getting better at mainstreaming adaptation into wider national development planning; and countries reported on over 1,600 implemented adaptation actions, mostly on biodiversity, agriculture, water and infrastructure. Climate fund support for new adaptation projects rose in 2024, although emerging financial constraints make the future unclear. Both public and private finance must step up to increase adaptation, taking care not to increase the proportion of debt instruments used by vulnerable nations'.[1530]

In November, Morningstar reported that global assets in open-end funds and electronic traded funds (ETFs) with a climate-linked mandate were valued at $644bn in June 2025,

[1527] https://www.ipe.com/news/net-purpose-buys-asset-owner-sdg-platform-combining-40trn-in-sustainable-assets/10133396.article
[1528] https://foodrise.org.uk/RoastingThePlanet/
[1529] https://impact-investor.com/ngos-call-for-cop30-action-on-rising-meat-and-dairy-emissions
[1530] https://www.unep.org/resources/adaptation-gap-report-2025

an increase of 8.5% from December 2024. Europe was responsible for 86% of these assets. Climate transition funds which back companies preparing for a low-carbon economy reached $318bn, while green bond funds and clean energy and technology funds were valued at $44bn billion each.[1531]

In November, an MSCI study found that extreme heat and rainfall were the biggest physical climate risks faced by global pension funds' listed equity portfolios. It estimated that listed companies risk losing $1trn in aggregate revenues per annum as a result of business disruption caused by climate-related events. MSCI analysed 500,000 physical assets owned by 11,000 companies across the globe, and found that 55% of these companies 'face significant and active physical hazards today', such as heat stress, water scarcity, and flood risk. Around 25% of companies' assets are concentrated in high-hazard zones, such as the US Gulf Coast, coastal China and India. MSCI examined the listed equity portfolios of 18 large pension funds with combined assets of more than $4trn, including the Pension Protection Fund, PensionDanmark, Pensionskasse des Bundes PUBLICA, Universities Superannuation Scheme, Norges Bank Investment Management and Stichting Pensioenfonds ABP. It said that: 'Some portfolios carry as little as 14% exposure, while others shoulder up to 61%'.[1532]

In November, XPS's fifth annual *Investment Fund ESG Rating Review* reported that investment firms' progress on ESG and climate strategies had declined, with the proportion rated 'green' falling to 64%, down from 72% in 2024 and 85% in 2023.[1533]

In November, the UK government set up the Office for the Impact Economy (OIE) to support social impact investing, following a recommendation by the Social Impact Investment Advisory Group (SIIAG), whose membership included the Impact Investing Institute. The OIE's aim is to unlock £100bn of untapped capital for impact investing in areas such as affordable housing, community energy, education and healthcare. A report from social investor Better Society Capital (BSC), also a SIIAG member, estimated that the UK's social impact investment was £11.2bn in 2024. There were around a 100 funds, intermediaries and social banks engaged in social impact investing, including both real assets and investments into social purpose organizations. BSC identifies four types of investment: social and affordable housing (54% of the market), social lending to charities and social enterprises (39%), impact venture (7%), and social outcomes contracts (1%). The report envisaged wider use of public, private and philanthropic capital, using mechanisms, such as match funding, blended finance, guarantees and social outcomes partnerships. In July, also following a SIIAG recommendation, the government launched a £500m Better Futures Fund to pay for social outcomes that improve conditions and create opportunities for vulnerable children and young people over the next decade. Pension funds, such as the South Yorkshire Pension Authority, were becoming increasingly involved in place-based investing and other social impact allocations. Charitable

[1531] https://funds-europe.com/__trashed-16/
[1532] https://www.ipe.com/news/msci-extreme-heat-and-rainfall-biggest-climate-risks-for-pension-funds/10133618.article
[1533] *Insurance Asset Management*, 25 November 2025

foundations and endowments were also increasingly prioritising impact to create social value as well as financial returns.[1534]

In December, the Network for Greening the Financial System reported that its Phase V long-term scenarios for assessing physical climate risks were based on an academic paper by Kotz et al. (2024) – from the Potsdam Institute for Climate Impact Research – that contained an error and has since been retracted from the journal *Nature*.[1535] The paper had used a 'damage function' to estimate the economic impact of climate change which indicated that global economic output could fall by as much as 62% by 2100 under the high emissions scenario. However, the authors subsequently found an error in the GDP data for Uzbekistan between 1995 and 1999 which resulted in a substantial overestimation of the potential economic damage. When the 'damage function' was re-estimated, the potential fall in economic output was lower at 23% by 2100. A number of banks, including Lloyds, NatWest and HSBC, confirmed that they used the NGFS research to identify the sectors most exposed to the net zero transition and to set their lending policies (although they would not say precisely how).[1536]

In December, President Donald Trump signed an executive order targeting proxy advisory firms ISS and Glass Lewis, claiming they use 'enormous influence' to advance politically-motivated agendas related to ESG. The order directs the SEC, FTC and DOL to review existing rules and potentially develop new ones to increase oversight of the proxy adviser industry. JPMorgan Chase CEO Jamie Dimon had previously criticized these firms, labeling them a 'cancer' and accusing them of promoting ESG interests rather than focusing on financial matters.[1537]

In December, a report from the Climate Policy Initiative found that pension funds were more effective in implementing their climate targets and strategies than other financial institutions, such as banks and asset managers. Measures included fossil fuel exclusion targets, policy advocacy and climate risk management. The study covered 594 pension funds with a combined $22.5trn under management or ownership (AUM/O), representing 78% of global pension assets. However, the report said that 'targets must now improve in quality', since only a third of the pension funds had a climate investment target, while only 40% had fossil fuel exclusion or phase-out targets.[1538]

---

[1534] https://www.gov.uk/government/groups/office-for-the-impact-economy; https://impact-investor.com/uks-new-impact-office-potentially-catalytic-for-social-investment; https://impact-investor.com/uk-social-impact-investment-market-reaches-11-2bn-up-10-on-2023

[1535] Maximilian Kotz, Anders Levermann and Leonie Wenz (2024) 'The Economic Commitment of Climate Change', *Nature*, 628: 551–557. This paper is known as KLW24.

[1536] https://www.ngfs.net/en/press-release/statement-regarding-physical-risk-estimates-phase-v-ngfs-long-term-scenarios; https://www.telegraph.co.uk/business/2025/12/14/banks-under-fire-for-using-flawed-net-zero-study. For an analysis of the background to the KLW24 paper, see Andrew Stuttaford (2025) Climate Modeling with Uzbek Characteristics, *National Review*, 19 December.

[1537] pionline@e.crainalerts.com, 15 December 2025

[1538] https://www.ipe.com/pension-funds-take-climate-targets-more-seriously-than-other-financial-institutions/10134308.article

**COP30 – November 2025**

In November 2025, COP30 took take place in in Belém, Brazil.[1539] The key goals were: reinforcing multilateralism and cooperation, connecting climate change to individuals and the economy – via nationally determined contributions (NDCs), each country's 5-year national plan to address climate change – and accelerating implementation.[1540]

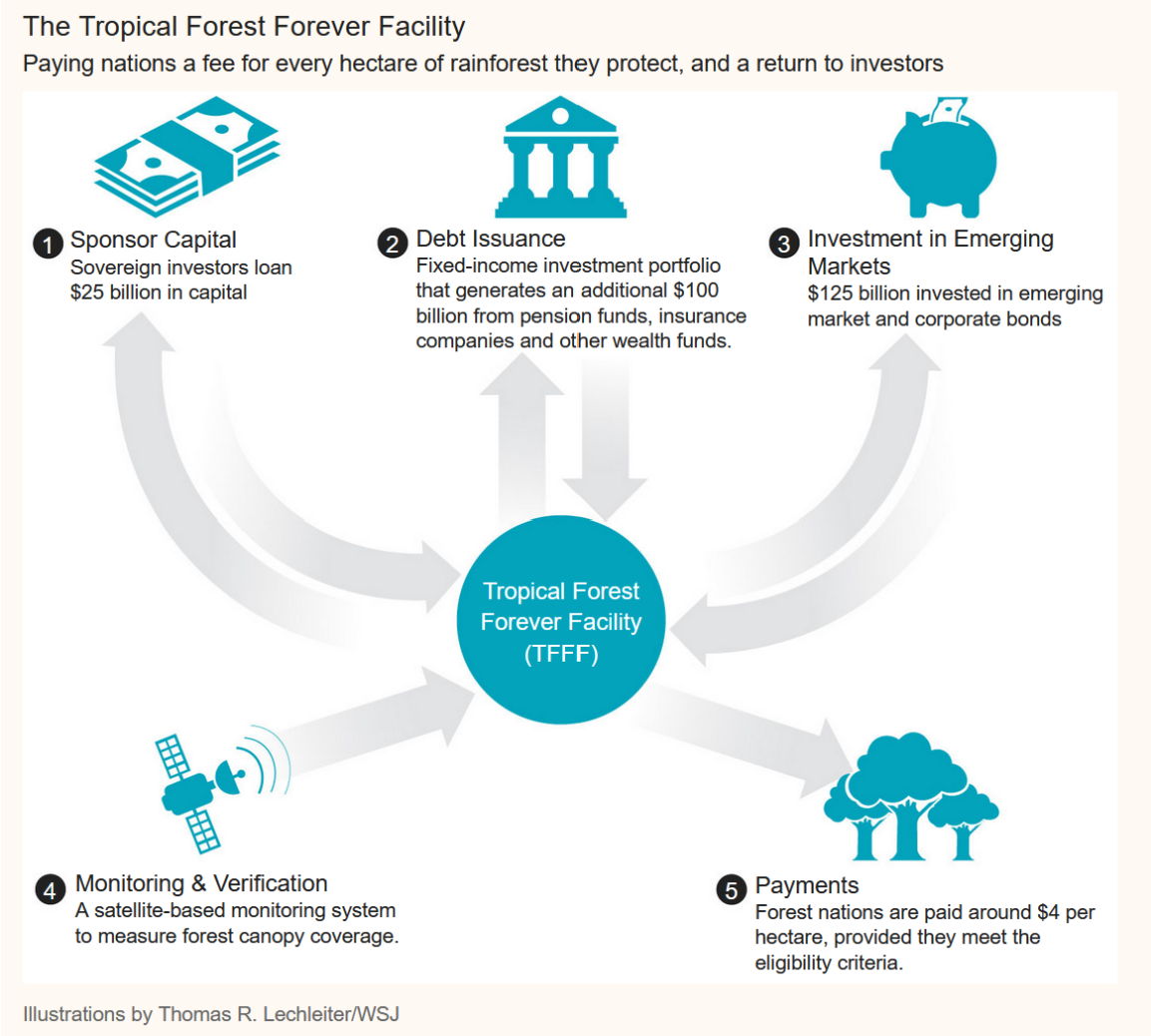
The BBC described the outcome of the event as follows: 'In three decades of these meetings aimed at forging global consensus on how to prevent and deal with global warming, this will go down as among the most divisive. Many countries were livid when COP30 in Belém, Brazil ended … with no mention of the fossil fuels that have heated up the atmosphere. Other nations - particularly those with most to gain from their continued production - felt vindicated. The summit was a reality check on just how much global consensus has broken down over what to do about climate change'.[1541] There was no official US delegation and China avoided taking any strong positions during the discussions.

The Brazilian presidency of COP30 released a final package termed the 'global mutirão' ('collective efforts'). It was an attempt to draw together controversial issues, such as finance, trade policies and meeting the Paris Agreement's 1.5C temperature goal. A 'mechanism' to help ensure a 'just transition' globally and a set of measures to track climate-adaptation efforts were also agreed. The need for adaptation was prevalent throughout the conference. A new deal was agreed to triple climate finance provided to developing countries by 2035.[1542]

A key focus of the conference was 'catalytic capital', a form of leveraged finance where a small sum of capital is used to attract a much larger sum. This often involves multilateral development banks and private banks. The Brazilian finance ministry and the UN-backed Green Climate Fund launched a $400 million fund aimed at bringing in $1 billion in capital. The Rockefeller Foundation launched a $5.4 million investment to help support regenerative agriculture. The Gordon and Betty Moore Foundation launched Catalytic Capital for the Agricultural Transition to support sustainable soy and cattle farming without adding to habitat loss in Brazil; it had $50 million in initial funding and aims for total funding of $200 million. The Tropical Forest Forever Facility, with an initial $25bn in sovereign loans, aims to mix sovereign wealth and private capital in order to pay rainforest nations for forest protection and provide a return to investors – see Figure 20.

[1539] https://www.un.org/en/climatechange/cop30
[1540] https://commonslibrary.parliament.uk/research-briefings/cbp-10357
[1541] https://www.bbc.co.uk/news/articles/cp84m16mdm1o
[1542] https://www.carbonbrief.org/cop30-key-outcomes-agreed-at-the-un-climate-talks-in-belem/

**Figure 20: The Tropical Forest Forever Facility**




Tariye Gbadegesin, CEO of the Climate Investment Funds, a multilateral lender launched in 2008, said focusing leveraged finance on adaptation is key for developing nations. CIF has so far invested $12.5bn in adaptation and resilience. The final deal at COP30 said that adaptation finance would be tripled to $120bn a year by 2035.[1543]

**Three key sustainability issues: biodiversity, natural capital and the circular economy**

We now turn to three key sustainability issues attracting the attention of pension schemes: biodiversity, natural capital and the circular economy.

[1543] https://www.fnlondon.com/articles/state-aid-for-sustainability-is-dwindling-climate-leaders-are-turning-to-private-markets-06844eae?

## Biodiversity

Mark Thompson (2023),[1544] a pension scheme trustee, argues that pension funds should consider biodiversity on their investment strategy:

> *Biodiversity is the variety of animals, plants, fungi and micro-organisms that make up the natural world. These species and organisms work together in ecosystems to maintain balance and support life. The planet's biodiversity is being seriously depleted, threating the viability of human existence. Since 1970, the Earth's wildlife populations have fallen by almost 70% – a result of deforestation, excessive human consumption and industrial scale pollution.*[1545] *Mother Nature's cupboard cannot be raided forever without serious consequences. ...It is estimated that around half of the world's GDP is dependent on nature.*
>
> *Against this background, there are four possible risks supporting why trustees should incorporate biodiversity considerations into their investment processes:*
>
> - *Companies that rely on threatened ecosystems will suffer from increased financial risk, with negative effects on their share prices and credit ratings.*
> - *Like climate change, there is transition risk, as governments legislate to mitigate the systemic risk of biodiversity loss.*
> - *Companies that exploit unpriced biodiversity externalities run the risk of reputational risk as media and public opinion turns against them with the resultant impacts on shareholder value.*
> - *Finally, schemes are unlikely to reach their climate net-zero objective without significant improvements in biodiversity loss. This is because marine and terrestrial ecosystems are the sole sinks of anthropogenic carbon emissions.*
>
> *In December 2022, almost 200 countries signed up to the UN Biodiversity accord.*[1546] *The accord commits to halting and reversing biodiversity loss by 2030. Implementation will be key to the accord's success and that will need increased legislation around the globe.*
>
> *However, in doing this, unlike climate change (which is essentially a case of controlling carbon emissions), biodiversity has many facets, and they are location-specific. This makes constructing a framework to manage biodiversity risks, and develop disclosure requirements, more complicated. This is the challenge the Taskforce on Nature-related Financial Disclosures (TNFD) has taken up. It is sensibly adopting the framework pioneered by the TCFD to build on.*

[1544] Mark Thompson (2023) Biodiversity: What trustees need to know, *portfolio institutional*, 17 January; https://www.portfolio-institutional.co.uk/opinion/biodiversity-what-trustees-need-to-know/

[1545] If the global average temperature rises above 1.5°C, this could constitute a threat to 20-30% of all remaining species.

[1546] The COP15 Kunming-Montreal Global Biodiversity Framework discussed above.

Assets managed by funds focused on biodiversity increased from $525m to $1.3bn between 2020 and 2022. However, the Convention on Biological Diversity estimates that to reverse biodiversity losses would require global investment in conservation of $536bn annually by 2050, while current expenditure is only $133bn per year.[1547] In January 2024, 320 organizations across more than 46 countries and representing US$14trn in assets under management committed to making nature-related disclosures based on TNFD recommendations. These included PwC, EY Global, Candriam, Cardano, Robeco, Van Lanschot Kempen, the UK Local Government Pension Scheme pools Brunel Pensions Partnership and London CIV, UK asset managers such as Fidelity International and Schroders, and the London Stock Exchange Group.[1548]

The UN's COP 16 Biodiversity Conference took place in Cali, Colombia in October-November 2024. A key aim was to assess progress on the Kunming-Montreal Global Biodiversity Framework agreed at COP15. However, only 44 of 196 countries submitted their National Biodiversity Strategies and Action Plans at COP16. Another aim was to check progress on the Global Biodiversity Framework Fund (GBFF) which was set up at COP15.[1549] The GBFF aims to help countries achieve the Kunming-Montreal Global Biodiversity Framework goals and targets with a strategic focus on strengthening national-level biodiversity management, planning, policy, governance, and finance approaches. At COP16, a total of $396mn was pledged to the GBFF by Austria, Canada, Denmark, France, Germany, Japan, Luxembourg, New Zealand, Norway, Province of Québec, Spain, the UK and others. Yet another aim was to persuade developed nations to commit at least $20bn annually by 2025 and and at least $30 billion a year by 2030 to support conservation efforts in the Global South.[1550]

Some fund managers are integrating biodiversity into their listed equity strategies. For example, AXA IM's 'biodiversity strategy aims to achieve long-term investment returns by investing in innovative companies that can deliver a positive and measurable outcomes'. It applies both the Kunming-Montreal Global Biodiversity Framework and the Global Impact Investing Network (GIIN)'s framework. It is focusing on three solutions that will contribute to stopping biodiversity loss by 2030 and have a net positive impact on biodiversity by 2050:

- Sustainable food and agriculture - reducing the use of water, fertilisers, pesticides, and pollution while increasing food production helped by shifting consumption to meat and dairy alternatives.
- Responsible production and consumption – increasing resource efficiency and reducing pollution through recycling, sustainable materials, and recirculation.

[1547] CAMRADATA (2023) Biodiversity; https://s42854.pcdn.co/wp-content/uploads/2023/12/Biodiversity-whitepaper.pdf
[1548] https://www.pensionpolicyinternational.com/uk-pension-funds-to-begin-tnfd-reporting/
[1549] https://www.thegef.org/what-we-do/topics/global-biodiversity-framework-fund
[1550] https://en.wikipedia.org/wiki/2024_United_Nations_Biodiversity_Conference; https://www.nature.org/en-us/what-we-do/our-priorities/protect-water-and-land/land-and-water-stories/biodiversity-global-conference/

- Resilient infrastructure – modernising ageing water networks to reduce water consumption and pollution, and using the latest science and technology to build next generation sustainable infrastructure designed with biodiversity in mind.[1551]

## Natural capital

Natural capital is a new asset class in which land is used to generate an investment return. There are three sub-categories: food production (the traditional use of land), afforestation (for carbon sequestration), and timber (as an alternative to steel and concrete in real estate construction). But with total productive land in scarce supply, there is an increasing competition over these uses.

The outcome in any particular country will depend on the price of carbon generated by the country's emission trading scheme. If demand from companies for carbon offsets increases the price of carbon credits, this makes carbon farming more attractive.

For example, in New Zealand, which is one of the world's highest per-capita carbon emitters (because of its red meat industry), carbon credits are above US$50 per tonne. This has resulted in prime farmland being sold to forestry investors for NZ$20,000 per hectare, up from NZ$4,000 per hectare, reflecting the higher net present value of the cash flows that can now be generated from it. This, in turn, has led to criticism from the red meat industry (Beef + Lamb New Zealand) which is forecasting significant economic damage to the sector and its rural communities.

The University of Melbourne's *Land Gap Report*, published in November 2022, has the following warning: 'Governments' over-reliance on carbon removal could push ecosystems, land rights and food security to the brink – with new land area equivalent to 50% of the world's croplands currently being required to meet [climate pledge] targets. Climate pledges should focus on protecting and restoring existing ecosystems with carbon benefits'.

Asset manager Gresham House has produced a Forest Charter, outlining six core pillars for investment managers, which include biodiversity and integration with the community.[1552] It argues that a long-term sustainable supply of timber is 'enabling the world to transition to a lower carbon, sustainable model, through the continued replacement of concrete and steel as building materials'.[1553]

According to Florence Chong (2023): 'Global asset managers now see as a central tenet of their management practices an ability to deliver benefits to surrounding communities in the first instance, then to the wider community. An ongoing emphasis on sustainability, preservation, biodiversity and rehabilitation of degraded land is seen as paramount. They point out that, in the first instance, they are accountable to their investors as to how both

[1551] https://core.axa-im.com/responsible-investing/insights/why-and-how-integrating-biodiversity-listed-equity-strategies
[1552] https://greshamhouse.com/forest-charter/
[1553] https://greshamhouse.com/news-media/global-timber-outlook/

carbon credits are generated and the timber products produced. Increasingly, too, they are under no illusion that land is finite, and that their ongoing viability as businesses depends on co-existing with other forms of land use, especially farmland'.[1554] Further, investors in natural capital assets will have to take into account both climate mitigation and climate adaptation and understand the physical risks to their portfolios.

In February 2024, it was reported that most of the 50 largest natural capital investors are from North America. The largest is Canada's Public Sector Pension Investment Board (PSP Investments) with €8.4bn in assets. This is followed by the US TIAA (General Account) with €5bn and Canada's BCI with €3.5bn. US public pension plans have been investors in timberland and farmland for a considerable time. The largest investor outside the US is the Dutch ABP pension fund with €2.9bn in assets.[1555] In total, the 50 largest institutional natural capital investors owned €70.6bn at the end of 2014, equal to over 1% of their total assets.[1556]

An example of the social benefits of protecting natural capital is the US reforestation program which began in the 1920s. Since then, 15m hectares have be reforested in the eastern US. This has created a 'warming hole' over the areas covered where temperatures have flatlined or even fallen, despite a warming trend elsewhere in the US.[1557]

In January 2025, the First Sentier MUFG Sustainable Investment Institute commissioned a report from Pensions for Purpose which found that 65% of asset owners in the UK were incorporating nature and biodiversity into their sustainability strategies, while a further 20% planned to do so. The report emphasized the need for the financial sector to tackle biodiversity risks, with asset owners increasingly aware of the dangers of biodiversity loss. Pensions for Purpose research manager, Bruna Bauer, said that it was financial materiality, rather than regulatory pressure, that had emerged as the primary reason for asset owners to act: 'Biodiversity loss poses tangible risks to investments, including supply chain vulnerabilities and ecosystem fragility, prompting schemes to proactively protect their portfolios. Asset owner respondents have realized ignoring nature-related risks is not just a sustainability issue but has financial consequences too, leading to the integration of nature into sustainable strategies before more regulation mandates it'.[1558]

The risks of ignoring nature-related risks could lead to 'planetary insolvency' according to a report by the UK Institute and Faculty of Actuaries entitled *Planetary Solvency – Finding our Balance with Nature*.[1559] The report defines 'planetary solvency' as 'managing human

[1554] Florence Chong (2023) Natural capital: food, timber or carbon?, *IPE Real Assets*, January/ February; https://realassets.ipe.com/forestry-agri/natural-capital-food-timber-or-carbon/10064740.article
[1555] https://realassets.ipe.com/special-reports/top-50-natural-capital-investors/10071197.article
[1556] https://realassets.ipe.com/special-reports/holistic-natural-capital-strategies-take-shape-in-investors-minds/10128328.article
[1557] https://www.theguardian.com/environment/2024/feb/17/us-east-trees-warming-hole-study-climate-crisis
[1558] https://www.pensionpolicyinternational.com/uk-financial-materiality-forcing-nature-and-biodiversity-into-sustainability-strategies/
[1559] https://actuaries.org.uk/document-library/thought-leadership/thought-leadership-campaigns/climate-papers/planetary-solvency-finding-our-balance-with-nature/

activity to minimise the risk of societal disruption from the loss of critical support services from nature'. The report concludes that there is an increasing risk of 'planetary insolvency', i.e., 'an increasing risk of severe societal and economic disruption caused by a breakdown in critical ecosystem services. This could include the provision of food and water and regulation of the climate. Therefore, catastrophic or extreme impacts are plausible unless decisive action is taken to mitigate climate and nature risks'.

The report has five recommendations to mitigate the risk of 'planetary insolvency':

1. Implement planetary solvency assessments to provide clear global systemic risk information for realistic and effective global risk management
2. Set planetary solvency limits that respect planetary boundaries, including revisiting climate goals and developing metrics to monitor planetary health
3. Enhance governance structures to formalize planetary solvency and provide transparent, easy-to-digest assessments for relevant bodies and the public
4. Build policymaker capacity on systemic risk management, enhancing understanding of the risks and interdependencies, and embedding risk outputs within current risk management processes
5. Take action to mitigate risk through incentives and policy design, as well as exploring options to limit global warming

The report introduces illustrative outputs for planetary solvency risk assessments in the type of format that might be provided to a risk committee. This includes an assessment of risk appetite alongside a risk dashboard. It sets out the current risk position and trajectory across the different dimensions of: climate, nature, society and the economy.

In March 2025, natural capital investment manager New Forests launched a fund to help Japanese paper-products manufacturer Oji Holdings meet its 2030 environmental goals. Oji Holdings will invest US$300m to establish Future Forests Innovations Fund which will invest in forestry plantations in Southeast Asia, North America, Latin America and Africa. It is targeting an additional 1.5m $tCO_2e$ p.a. of net sequestration by 2030 from the forestry assets it acquires. It already owns 635,000 hectares of plantations globally and will invest in an additional 70,000 hectares, including greenfield and brownfield assets.[1560]

In March 2025, the British Standards Institution (BSI) released a government-backed green finance standard – as part of the Nature Investment Standards Programme – to encourage investment in nature restoration and prevent greenwashing. The standard will promote investment in projects such as wetland restoration, water quality improvement, flood resilience, and habitat creation. The BSI is also launching a consultation on the first version of a Natural Carbon Standard which will gather market views on high-integrity principles

[1560] https://realassets.ipe.com/news/new-forests-launches-300m-fund-to-help-japanese-corporate-meet-2030-goals/10129587.article

for projects selling nature-based carbon credits in UK markets. These credits will consist of habitats which store carbon, such as woodlands or peatlands.[1561]

In March 2025, a report entitled *Balancing Act: Aligning Climate And Nature* was released by Savvy Investor and Nuveen.[1562] The report investigated the intersection between net-zero investing and nature conservation and highlighted the unintended risks of focusing solely on emissions reduction. It considered how climate-driven investment strategies can inadvertently harm biodiversity and outlined a framework for integrating nature considerations into investment decision-making for investors seeking to balance decarbonization with ecosystem preservation. The report suggested that to bring nature-positive investing into financial decision-making most effectively, investors should consider a whole-portfolio approach that encompasses both systemic- and event-based risks. This implies looking at how nature-related impacts occur across different asset classes and identifying opportunities to support ecosystem restoration and resource efficiency. The report proposes some key investment strategies:

- Prioritizing high-impact themes: Focus on sectors and activities with the greatest environmental footprint, such as land use change, resource consumption, and pollution generation. Identifying material risks within corporate value chains can help direct capital toward the most impactful areas.
- Using science-based assessment frameworks: Metrics such as the Science Based Targets Network (SBTN) provide structured methods for evaluating corporate sustainability commitments. Investors can use these frameworks to measure progress toward nature-positive outcomes.
- Exploring fixed-income solutions: A specific example is a $225m Amazon reforestation bond issued by the World Bank, which ties financial returns to measurable carbon removal outcomes. This type of innovative financial instrument can channel capital toward conservation efforts while generating returns.

Further, the report said it was of critical importance to address nature risks across different asset classes, such as equities, corporate debt, and structured financial products. Given that nature risks are embedded across multiple industries, creating and using a holistic strategy that incorporates biodiversity and natural capital considerations is necessary for investors who wish to manage long-term financial risks.

In April 2025, the IFRS Foundation and the Taskforce on Nature-related Financial Disclosures (TNFD) agreed to create better guidelines for improving nature-related financial disclosures, building on the TNFD recommendations in the ongoing work of the International Sustainability Standards Board (ISSB). The ISSB said: ‘Our collaboration with the TNFD is a clear signal to the market that we are committed to reducing

[1561] https://www.bsigroup.com/en-GB/products-and-services/standards-services/the-nature-investment-standards-programme/; https://www.ipe.com/news/uk-launches-nature-finance-standards-to-prevent-greenwashing/10129677.article

[1562] https://www.savvyinvestor.net/sites/default/files/node/paper/file/savvyreport_nuveen_mar2025_final.pdf

fragmentation in sustainability disclosure while meeting the need for relevant and high-quality information for capital markets'. The TNFD said: 'Nature is essential to our economies and our future. Our collaboration with the ISSB is a major step toward making nature visible in businesses reporting and how capital is allocated. Climate-related standards have already moved markets, and we are pleased to continue to support ISSB efforts that bring the rest of nature into global reporting practice. Stronger standards mean stronger businesses, and a healthier, more resilient planet for all of us'.[1563]

In September 2025, the World Economic Forum published *Finance Solutions for Nature: Pathways to Returns and Outcomes* which offers institutional investors, banks, asset managers and development institutions ten finance solutions for investments in nature:[1564]

1. Sustainability-linked bonds (SLBs): Commercial bonds tying coupon rates to nature-related targets for corporates or governments. To scale up, SLBs need stronger triggers, clearer metrics and closer alignment between issuers and investors.[1565]
2. Thematic (or use-of-proceeds) bonds: Bonds with proceeds earmarked for nature projects. Scaling-up requires clearer guidance and aggregation to improve outcomes for issuers and investors.
3. Sustainability-linked loans (SLLs): Flexible debt, linking interest rates to nature-related targets. SLLs need simpler verification, standardized metrics and stronger triggers to drive nature-positive lending.
4. Thematic (or use-of-proceeds) loans: Loans for specific nature-related projects. Greater clarity on taxonomies and aggregation is needed to enhance capital flows.
5. Impact funds: Funds investing in nature-positive outcomes, often accepting higher risk or longer pathways to returns. Scaling-up requires a stronger pipeline of investable projects and better governance.
6. Natural asset companies (NACs): Publicly and privately listed companies that convert the full economic value of nature into financial flows via equity models. NACs hold significant potential but need more transactions for price discovery and replicable investment blueprints.
7. Environmental credits: Tradeable certificates for verified environmental benefits, used in compliance or voluntary markets. Scaling-up needs integrity principles, unified standards and stronger local community engagement.
8. Debt-for-nature swaps (DNS): Mechanisms to restructure sovereign debt in exchange for conservation or restoration commitments, with investable components including bonds and loans. DNS need better governance and standardization, plus an expanded pipeline of eligible debt to deliver conservation funding.

[1563] https://www.ipe.com/news/ifrs-joins-forces-with-tnfd-to-improve-nature-related-financial-disclosures/10129953.article

[1564] https://reports.weforum.org/docs/WEF_Finance_Solutions_for_Nature_2025.pdf

[1565] The first issuer of a SLB was Chile in 2021 which tied coupons to emissions reduction and renewable electricity targets. The second issuer was Uruguay in 2022 which linked its coupons to deforestation limits and commitments to increase forest cover; https://impact-investor.com/slbs-find-their-place-within-em-sovereign-debt-says-ninety-one/

9. Payments for ecosystem services (PES): Contracts rewarding conservation for specific ecosystem services, driven by the public sector. Private sector schemes require longer contracts, aggregation and supply chain integration to scale up.
10. Internal nature pricing (INP): Unexplored, voluntary shadow pricing or fee-based tools to incentivize nature-positive performance in companies or across investment portfolios, similar to internal carbon pricing (ICP).

In November 2025, Van Lanschot Kempen Investment Management released a report entitled *Building nature-positive portfolios* which argued that 'For investors seeking to create positive impact, private markets are uniquely positioned to deliver nature-positive outcomes. Private equity, private debt, infrastructure, farmland and forestry (real assets) enable capital to be invested in transformative business models and projects that combine financial returns with nature restoration'.[1566]

In January 2026, Funds Europe and Gresham House released a report *Perspectives on Nature* which identified significant sources of sustainable and uncorrelated risk-adjusted returns from investing in natural capital and assets such as sustainable agriculture, forests and timberland, and land assets acquired on the basis of legislation encouraging a market in biodiversity net gain (BNG).[1567] Olly Hughes, managing director Forestry at Gresham House, pointed to factors such as the structural shift towards a circular bioeconomy driving demand for timber versus carbon-intensive materials, such as steel, concrete and plastic. The forestry market is also shifting away from traditional owners such as HNWIs and family offices towards institutions, including pension funds, insurers and endowments.[1568]

In February 2026, a report from Pensions for Purpose entitled *Biodiversity & Natural Capital: where pension funds are and what comes next?* found that UK pension funds were increasingly treating natural capital as a mainstream asset class, with internal rates of return of 8-10% from forestry and sustainable agriculture and up to 20% in emerging markets (EMs). The returns comprise cash flows from timber, crops, and long-term land appreciation. Pension funds mentioned low correlation with equities and bonds, along with positive links to inflation, as the primary drivers of allocations. The higher return targets in EMs were due to faster biological growth rates and lower land costs, rather than to greater risk tolerance. The majority of pension funds had made initial allocations only in the past two years, mainly as sub-allocations within infrastructure or private equity mandates rather than as standalone asset classes. However, the funds also mentioned limited internal expertise, inconsistent track records outside forestry, and the technical complexity of assessing both environmental and financial performance as key constraints limiting further investment; liquidity concerns were also mentioned. The report argued that more

[1566] See also: https://www.vanlanschotkempen.com/-/media/vlk/vlk-im-documents/news-and-knowledge/whitepapers/vlk-natural-capital-farmland-document.pdf
[1567] The specific regulatory requirement in England, effective from February 2024, that requires that developers leave biodiversity in a measurably better state than before development took place.
[1568] https://funds-europe.com/valuing-natural-capital/; https://funds-europe.com/gresham-house-natural-capital-report/

institutional-grade investment structures, aggregation vehicles and proven case studies would be required before allocations could scale meaningfully.[1569]

A number of studies have proposed measures to improve the design of nature-based markets. For example, Estelle Cantillon, Eric F. Lambin and Beatrice Weder di Mauro in *Designing and scaling up nature-based market*s (2025)[1570] point out that:

*The biosphere is a net carbon sink. Carbon sequestration in plants and soils currently absorbs around 4.8 Gt of $CO_2$ annually. By some estimates, it could contribute 37% of cost-effective emissions reductions through 2030. ...[L]and use and forests made up a quarter of the emissions reductions planned under the nationally determined contributions (NDCs) submitted by signatories of the Paris Agreement.*

*Nature is also a carbon stock. Natural forests cover 28% of global land cover and non-natural tree cover represents 2%. Carbon stored in all forests (accounting for all carbon pools – living biomass, dead wood, litter, soil organic matter and harvested wood products) is estimated to represent 870±61 Gt of carbon, of which tropical forests represent 54%. Preserving these forests is, therefore, essential. Emissions from deforestation are estimated to release around 7 Gt of $CO_2$ per year, cancelling and reversing the carbon absorbed through afforestation and reforestation.*

They then state the challenges with existing market solutions:

*Existing nature-based markets find their origins in the clean development mechanisms (CDMs) and Joint Implementation (JI) projects introduced by the Kyoto Protocol. CDMs involve investments in emissions reduction or carbon removal projects in developing countries. JIs are their equivalent for projects in developed countries. Both mechanisms are project-based and lead to the issuance of a credit recognising the emissions reduction or carbon removal associated with the project. Signatory countries could use them to meet their emissions reduction commitment under the Kyoto Protocol.*

*Current carbon and biodiversity markets build on the template set by the CDMs and JI mechanisms. They are also project-based. Several independent organizations have profiled themselves to set standards for what counts as an eligible projects and how carbon and biodiversity benefits are computed. They coexist alongside public international, national, and regional crediting mechanisms.*

---

[1569] https://www.pensionsage.com/pa/Nature-capital-now-a-mainstream-asset-for-UK-pension-funds.php

[1570] https://cepr.org/system/files/publication-files/257653-policy_insight_145_designing_and_scaling_up_nature_based_markets.pdf. See, also: Jean Pisani-Ferry, Beatrice Weder di Mauro and Jeromin Zettelmeyer (Eds, 2025) *Global Action Without Global Governance: Building coalitions for climate transition and nature restoration*, https://cepr.org/publications/books-and-reports/paris-report-3-global-action-without-global-governance-building; and Anna Fiore and Heather Grabbe (2025) Nature markets: how can credits and shares provide durable, additional finance?, https://www.bruegel.org/policy-brief/nature-markets-how-can-credits-and-shares-provide-durable-additional-finance

*Additionality, permanence, baseline accuracy, and traceability are central criteria in all standards.* Additionality *means that the project would not have happened absent external funding.* Permanence *requires that the benefits from the project are permanent. This condition is especially demanding for nature-based projects given the risks of wildfires, pests, and other hazards impacting any natural resource.* Baseline accuracy *refers to the correct estimation of the counterfactual outcome absent the project. It ensures that the benefits of the project are properly quantified. This includes accounting for any leakage whereby the project displaces, but does not prevent, nature-harming activities. Finally,* traceability *ensures that the benefits generated by a project are not claimed twice. This is done through registries that record credits, verified benefits generated, and retirement (the use of the credits for compliance or offsetting).*

*Projects are diverse: some are based on nature and others on technology. Nature-based projects can focus on climate benefits, biodiversity benefits, other ecosystem services (e.g., water cycling, soil protection), or any combination thereof. Some reduce emissions relative to a business-as-usual situation (avoided emissions), others physically remove carbon from the atmosphere (carbon removal). Reforestation and nature restoration are examples of nature-based carbon removal projects. Conservation can count as a nature-based emissions avoidance project if the case is made that the forest would likely be converted or degraded without funding.*

*Credits are sold directly by project developers, standard-setting organizations, or independently run trading platforms. Buyers include companies, organizations, and individuals eager to offset their emissions. Additionally, some carbon credits are eligible for carbon emissions compliance schemes such as the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) or California's cap-and-trade scheme.*

*The voluntary carbon market makes up for the bulk of the issuance and trading. Liquidity and transparency are low. Prices vary largely according to projects, reflecting both the quality of the credits issued and the co-benefits of the projects. For example, carbon removal credits tend to trade at a higher price than carbon avoidance projects because the baseline is more certain and over-crediting less likely. Likewise, credits offering co-benefits beyond carbon and recent vintages trade at a premium. Total transaction costs, including certification, monitoring, reporting, and trading, are large and are absorbed by intermediaries that are only service providers. Total transaction costs of the order of 40% of the sale price are common, leaving little for the local project developers.*

*Several scandals have shattered buyers' confidence in the voluntary carbon market. Researchers have documented the absence of additionality of projects, large and systematic over-crediting of the benefits generated and leakage. These concerns were further publicised when a syndicate of investigative journalists reported in January 2023 that more than 90% of rainforest carbon offsets certified by Verra, one of the largest standard setters, did not represent genuine carbon reductions. If this was not enough, a number of large-scale forest fires in 2023 and 2024 destroyed forests planted through carbon offset projects, cancelling all the claimed (and sold) climate benefits. In 2024, the Science-Based Target*

*Initiative carried out a stock-taking exercise on the use and effectiveness of carbon credits. The Initiative concluded that the existing evidence pointed to their ineffectiveness in delivering their intended mitigation outcome.*

*These concerns about credit quality and integrity have led to large drops in prices, especially for nature-based credits. Several initiatives are underway to promote and rebuild trust, including a revision of certification standards and government-sponsored crediting mechanisms. These initiatives tend to raise standards for project qualification and governance. Some also address concerns about greenwashing on the demand side by developing guidelines for when using credits is legitimate as part of an organization's environmental strategy. This will improve the integrity and trust in the market, but is likely to come at the expense of large costs and therefore smaller scales. More importantly, these efforts do not address the issue of impermanence of nature benefits.*

The authors then propose a new market design for nature-based provision which has four building blocks: (1) a jurisdictional approach on the supply side; (2) a move from credits to shares that generate carbon and biodiversity dividends as the main asset to be traded; (3) a primary market organized as a crowdfunding market; and (4) a largely public governance of the market.

The first building block, jurisdictional approaches 'provide a number of advantages. First, their inclusive governance fosters greater buy-in and provides for a more holistic approach. Second, their larger scale and their alignment with the monitoring, enforcement, and regulatory levels reduces selection issues and leakage, and improves baseline accuracy'.

As a second building block, 'they propose that what is sold are not credits that recognise a flow benefit but instead shares in a nature-based provision project. In other words, buyers are investors. Their shares give them a right to carbon and biodiversity dividends, the currency of which is physical units (tCO2 and change in quality × ha or any other relevant metric to measure biodiversity benefit). They can use these to claim climate and biodiversity contributions. Shares in projects differ from credits in at least two important respects. First, credits are transactional – a company can buy a credit from a project one year and not the other. Instead, shares instil a longer-term perspective in investors, who will be willing to encourage sustainable forest management even if this decreases the rate at which carbon and biodiversity benefits are generated. … Second, unlike credits, dividends do not need to match the flow nature benefits of the project, year on year'.

The third building block is the design of the primary marke: 'The primary market refers to the market where shares in provision projects are first sold by jurisdictions. A challenge here is that projects – like the nature that underlines them – are highly multi-dimensional. The fact that what is traded is a share (i.e., a stock) rather than a credit (i.e., a flow) adds a time dimension to an already complex bundle of attributes. We propose to organize this primary market along the lines of equity crowdfunding Marketplaces'.

The fourth building block is market governance: 'Today, the voluntary carbon and biodiversity markets are largely privately governed. We propose to replace this private

market governance with a largely public and international market governance that sets minimal eligibility criteria for projects, define monitoring, reporting, and verification (MRV) protocol organizes the primary market, maintains registries, and provides public guarantees for projects. This will address today's market fragmentation and reduce transaction costs as a result'.

## Circular economy

A key feature of a sustainable future is the Circular Economy. This has been defined, by Amundi Asset Management, as an economy which 'allows [the production of] sustainable consumer goods, while protecting nature – by giving it time to regenerate – and ensuring the wellbeing of individuals. There is an urgent need to promote a society in which natural resources are protected, in which nature has the time to regenerate, where consumption is reasoned, where the life of goods is extended to the maximum and where waste is treated to be recycled in new products… We therefore need to move from a linear economic model to a circular economic model that will limit the damage to the environment, giving it time to regenerate by promoting the extension of the life span of produced goods – notably through eco-design, reparability, durability, and the second-hand market. It must also include better treatment of waste allowing raw materials to be reused to create new goods... thus closing the loop'.[1571]

One example of this is enhancing building efficiency through 'smart windows' that generate power, cool rooms and heat water. A smart window incorporates a thin layer of a semi-transparent photovoltaic (STPV) material between two panes of glass. The STPV layer absorbs most of the visible light passing through the window, provides some shading, and generates electricity to help power the building's cooling system.[1572]

Speaking at the Fiduciary Investors Symposium at Oxford University in November 2024, Gabriel Micheli, senior investment manager at Pictet Asset Management, pointed out that the planet had lost around three quarters of its species over the past 50 years and that biodiversity regeneration and restoration were essential for the planet's resilience. He said that regenerative agriculture is more resilient, reduces tilling and uses less pesticides and more nature-based solutions to ensure yields. Although circularity accounts for just 7% of the global economy, he predicted that the circular economy and recycling offer investors a huge opportunity.[1573] Speaking at the same Symposium, Ingrid Kukuljan, head of impact and sustainable investment at Federated Hermes Limited, also agreed that 'you can make money by investing in solutions. [But] if you don't start investing now there won't be any returns in ten years because the degradation will be so high. Take it seriously from a fiduciary duty point of view'. She also reminded delegates of the potential risks from not

[1571] The wheels of a Circular Economy go round and round, Amundi Asset Management, 26 January 2022; https://research-center.amundi.com/article/wheels-circular-economy-go-round-and-round

[1572] Abdelsamie, M. M., Ali, K., and Hassan Ali, M. I. (2025) Enhancing building efficiency: Multifunctional glazing windows with integrated semitransparent PV and selective liquid-filters, *Appl. Energy*, 377, 124723. See also: https://kuexplorer.ku.ac.ae/2025/09/09/smart-windows-help-power-heat-and-cool-buildings

[1573] https://www.top1000funds.com/2024/12/biodiversity-regeneration-set-to-become-big-investment-theme-in-future

stemming biodiversity losses: 'plants alone are responsible for around 40% of the medicine in the western world'.[1574]

## Investment and sustainability

Here we discuss how investors are responding to the climate change challenge.

### Integrating biodiversity into finance

Emmanuelle Sée, Head Equity Management, Swiss Life Asset Managers France, discusses the importance of integrating biodiversity into finance:

> *By integrating biodiversity into decision-making and investment practices, financial institutions can help protect the planet's natural resources while generating sustainable returns for investors and society. The economy's dependence on nature makes biodiversity loss a significant risk for companies, especially as regulations tighten.*
>
> ***Nature-related risk: a critical challenge for businesses.*** *Financial institutions must anticipate and incorporate both climate-related and nature-related risks into their business activities and investment portfolios. The degradation of biodiversity and ecosystems presents substantial threats to financial stability, including physical, transition, and systemic risks. Recent estimates suggest that annual cost of losing ecosystem services range from USD 4 trillion to USD 20 trillion (OECD).*
>
> ***Physical risks*** *result from the degradation of nature, which impacts economic activities – ranging from acute crises like natural disasters to chronic issues such as ecosystem decline. Sectors dependent on specific ecosystems are particularly vulnerable. For instance, the decline of pollinators can reduce agricultural yields, while large-scale pollution events, such as oil spills, can disrupt business operations.*
>
> ***Transition risks*** *include reputational and regulatory challenges as governments enforce stricter environmental regulations or as consumers become more environmentally conscious. Companies that fail to adapt to these demands risk being left behind as sustainable alternatives gain traction.*
>
> ***Systemic risks*** *refer to the broader implications of biodiversity loss on the global economy's resilience. Ongoing ecosystem degradation can undermine natural infrastructures, such as coastal wetlands that protect against storms, posing risks to both communities and businesses.*

[1574] https://www.top1000funds.com/2024/12/why-investing-in-biodiversity-champions-pays

*Addressing these risks is not just about compliance; it is essential for safeguarding the long-term viability of economic activity and ensuring the resilience of financial systems.*

***A nature-positive approach.*** *Companies and investors are increasingly adopting a 'nature-positive' approach, complementing their carbon neutrality efforts. This shift is influenced by international agreements like the Paris Accord, alongside rising governmental regulations aimed at enhancing environmental sustainability. The approach recognises biodiversity's essential role in ecosystem health and strengthening the resilience of global economies amid climate challenges.*

*This broader focus extends beyond climate to include biological diversity, encapsulated by the equation: Nature = Climate + Biodiversity. Nature is shaped not only by climate but also by the diversity and interactions among species. Integrating biodiversity into corporate strategies is key to meeting stakeholders' growing expectations regarding sustainability and environmental responsibility.*

*By pursuing a 'nature-positive' approach, businesses can minimize their environmental impact and actively contribute to preserving and restoring vital ecosystems. This involves strategies that protect biodiversity, restore degraded ecosystems, and align business models with the needs of the planet and its inhabitants.*[1575]

## The financial sector's pathway to sustainable investing

In April 2025, the Institut Louis Bachelier (ILB) released a report entitled *Financial sector's path to global climate goals*.[1576] The report argues that 'While numerous methodologies exist to assess the alignment of individual institutions or portfolios, a consolidated, sector-wide perspective is still largely missing'. Although the report recognises the importance of 'emission alignment' metrics, it calls for two additional metrics, 'transition alignment' metrics and 'financing alignment' metrics. It argues that 'Assessing consolidated climate alignment can reveal whether financial flows are being redirected at the scale and pace required to meet global climate targets'. This allows three complementary questions to be asked: 'Who provides financing, what does it finance, and what outcomes does it achieve in terms of alignment with climate goals?'. Answering these questions will make it easier to mobilize capital globally, since 'new annual flows can be aligned [to the transition to net zero] – while the accumulated stock of capital may not be, because of past misalignment of financial flows'. The report also suggested that 'To provide actionable insights, a robust assessment methodology should link individual institution performance with macro-level objectives. This requires reconciling diverse data

[1575] Emmanuelle Sée (2024) The new nature of business: integrating biodiversity into finance, Swiss Life Asset Managers, November; https://hub.ipe.com/asset-manager/swiss-life-asset-managers/the-new-nature-of-business-integrating-biodiversity-into-finance/10076605.supplierarticle

[1576] https://www.institutlouisbachelier.org/wp-content/uploads/2025/05/financial-sector-s-path-to-global-climate-goals-april-2025-1.pdf

inputs, ensuring transparency, and avoiding distortions. Accounting for the unique impact of different financial activities ensures that progress in one area does not overshadow gaps in others. By addressing these dimensions, consolidated alignment assessments can clarify whether financial institutions (FIs) are collectively contributing to global climate objectives'. The report then went into more detail about the three metrics:

> *FI Transition alignment approaches focus on evaluating whether individual financial institutions within a defined group are aligned with climate objectives. This approach answers the question: 'To which extent the chosen group is constituted of aligned financial institutions?'. These approaches are the simplest and most widely applied. They often assess institutions based on their commitments, governance, decarbonization levers such as engagement and adoption of frameworks such as science-based targets. However, variations in the definitions and quality of the methodologies used across different frameworks can make comparisons difficult. Steps to implement this approach include defining the criteria to define whether a specific institution is aligned or not, evaluating individual institutions against these criteria, and aggregating the results into a consolidated metric at group-level. Aggregation can be based on the number of aligned institutions, financial metrics, or emissions data, each with specific strengths and limitations. While these approaches provide a high-level overview, they have limitations. They do not establish direct links to emissions reductions or ensure alignment with global carbon budgets at the macro level. Additional research is needed to integrate data on financial flows and stocks and emissions to make this approach more robust and comprehensive.*
>
> *Financing alignment approaches focus on tracking the reallocation of capital towards climate-aligned investments away from 'climate-incompatible' investments. These approaches aim to assess whether financial flows (and stocks) are being redirected at the necessary scale and pace to meet global climate goals. These approaches can be applied to both instruments with known use of proceeds, such as green bonds, and those with unknown use of proceeds, such as corporate loans. Historically, they have been used in the context of macro analysis, unrelated to specific FIs, as well as at FI-level focussing on fossil fuels specifically. Increasingly, there are discussions of using this approach at FI-level for target-setting and monitoring across all types of assets in relation to the transition (solutions, credibly transitioning, incompatible). Bridging the gap between individual FIs and macro analysis to produce a consolidated alignment metric would involve defining what constitutes climate-aligned and incompatible financial flows and stocks, identifying current and projected flows, setting alignment benchmarks describing the pace and scale at which financial flows and stocks should be reallocated, and aggregating results. Key challenges include distinguishing between stock metrics (accumulated financial flows) and flow metrics (new financing activities), as well as addressing the lack of standardization in the classification of financial instruments and counterparties as net-zero aligned. The absence of robust tools to assess general-use financial instruments, to project future flows and stocks, and to derive benchmarks further complicates the analysis.*

*Advancing this approach will require enhanced data availability, improved methodologies for mapping financial flows and stocks to counterparties, and refined tools to assess alignment.*

*FI Emissions alignment approaches use the GHG [greenhouse gas] emissions data associated with financial institutions' activities as an input to the analysis. These approaches seek to address the ultimate objective of climate-related finance: achieving measurable reductions in greenhouse gas emissions. These approaches have historically been used by FIs to assess the alignment of their portfolios, using projected emissions. The same logic could be applied at the consolidated level, for a group of FIs. It would involve retrieving and harmonizing emissions data, addressing inconsistencies in reporting, mitigating double-counting risks, projecting future emissions and assessing alignment against decarbonization benchmarks. Yet, forward-looking emissions alignment metrics trying to project future emissions (and thus future emission reductions/avoidance) bring with them their own challenges: uncertainty of the projections, need to build a sound 'Business as Usual' reference scenario, attributability of the reduction/avoidance. [The report argues] that, in the context of consolidated alignment assessments, emissions' alignment approaches are best used as an ex-post assessment, to monitor whether FIs changing financing practices have had the desired impact on real world decarbonization. The main challenge includes the risk of 'paper decarbonization', where emissions reductions are only achieved through metric optimization (perimeter/methodological changes, adjustment of the portfolio exposure through divestment of some GHG-intensive companies to the profit of light-intensive GHG companies, without any actual effect on real-economy GHG emissions). Further research is needed to standardize methodologies, integrate emissions data with financial metrics, develop reliable tools to monitor emissions' reduction and aggregate the results relating to different asset classes and financial services. These efforts should focus on ensuring that these approaches capture the real-world impact of financial institutions' activities on emissions reduction.*

## The drivers of investment funds' allocation to sustainable investments

Annamaria de Crescenzio and Etienne Lepers (2024) consider the key drivers of investment funds' allocation to sustainable investments, particularly in emerging markets (EMs).[1577] Using a unique micro-level dataset on a detailed portfolio-level sample of the 37,000 largest investment funds globally and a unique classification of 'green' companies based on revenues in carbon solutions (renewable energy, green transport, and infrastructure), the authors find that:

[1577] Annamaria de Crescenzio and Etienne Lepers (2024) What Drives Capital to Green Companies in Emerging Markets: Evidence from Investment Funds;
https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4822081;
https://cepr.org/voxeu/columns/drivers-investment-funds-allocation-green-companies

- A key role is played by benchmarks. Inclusion in major indices, such as the MSCI EM equity index, was the single most important factor influencing global investment fund choices. For example, major EMs like China and Brazil, with substantial representation in these global benchmarks, were able to attract significant shares of green investments, 'reflecting the appeal of their green companies'.
- Developing robust green sectors can position countries as prime destinations for capital. Countries with high renewable energy generation and strong green exports were able to attract more capital. Conversely, structural barriers, such as concentrated ownership of listed companies, deter investment by limiting the availability of tradable shares. So maintaining openness and a favourable investment climate remains critical.
- There was no robust statistical evidence for a role of climate policies in influencing green investment shares in country portfolio allocations.

## Building sustainable investment strategies

How can investors build sustainable investment strategies? Bouchet and Shahyar (2024) offer a framework for achieving this which begins with certain building blocks (themes, levers and data) and ends with four categories of sustainable investment strategies (sustainable, transition, solutions, and ethical).[1578]

The themes range from local 'ESG' to global 'SDG'. There are three key types of lever: exclusion, allocation and engagement. Exclusion removes certain stocks from the portfolio; it is used as a response to non-sustainable activities, as a last resort when engagement fails, and to align with trustees' ethical considerations or resource constraints. Allocation applies a weighting scheme to the selected stocks, with the objective of either (1) maximizing sustainable metrics like ESG scores, carbon intensity, or average sustainable revenues or (2) ensuring a minimum allocation to certain market segments, e.g., companies offering climate solutions. Engagement builds relationships with companies and stakeholders. It begins with 'field building', the establishment of direct relationships with companies and with the fellow investors and regulators who can also influence a company's behaviour. This, in turn, leads to specific actions, such as 'Say on Climate' resolutions (e.g., ESG votes at AGMs) and collective investor initiatives like Climate Action 100+. The aim is to change corporate behaviour, particularly in transitioning non-sustainable activities to sustainable ones. Since this involves significant time and resources, investors are recommended to focus on specific themes and companies. The effectiveness of engagement is increased if exclusion by a group of investors remains a genuine possibility.

Data can be distinguished between primary and secondary. Primary data for sustainable investing reveals a company's state and activities. This is increasingly standardized, with metrics aligned with reporting requirements which emphasize climate mitigation. There is also more public data available, such as Urgewald's global coal exit list and the Finance

[1578] Vincent Bouchet and Shahyar Safaee (2024) Institutional equity portfolios: how can asset owners build coherent sustainable strategies?, *EDHEC Research Insights*, Summer 2024, 7-11.

Exclusion Tracker Initiative's aggregated exclusion list. Further, technological developments in web scraping and text analysis allow the generation of alternative ESG data. This has led to more reliable ESG primary data, making it easier to set exclusion and sustainable investment criteria. Secondary data are derived from primary data and are used to create ESG ratings. However, there are currently significant differences between ESG rating providers at both company and fund levels, mainly due to differences in the measurement of ESG attributes, rather than differences in scope or weight. There are also secondary metrics, chiefly related to climate change mitigation, but again there are big differences in measurement methodologies; nevertheless they can provide a useful basis for discussions with companies.

The themes, levers and data can be used to construct the four types of sustainable investment strategies. A sustainable investment satisfies one or more of the three ESG criteria of avoiding harm to environmental or social goals, contributing positively to these goals, and adhering to good governance standards. 'Harm' as a result of both activities (what a company produces) and behaviour (how the company produces) have to be defined, and an investor could assess them in terms of, say, the EU's 'do no significant harm' (DNSH) criteria or the UN's SDG framework, using primary data on, e.g., revenue distribution, consumption and production. A company can be considered to make a 'positive contribution' if its core activities meet one or more SDGs at a minimum threshold and the company also manages negative impacts from all activities and behaviour, consistent with 'do no harm'. Some organizations have set criteria for defining such investments, e.g., the Sustainable Development Investment (SDI) Asset Owner Platform.[1579] Again, primary data on revenues and production tend to be preferred for screening positive companies, since they focus directly on company activities; by contrast, secondary metrics such as ESG scores, tend to focus more on behaviour and often net off positive and negative contributions.

Investment strategies can range from 'alignment', where holdings align with values but no specific change is expected, to 'impact', where explicit improvements in activities or behaviour are targeted. Targets should ideally be derived from science-based or global standards, such as the Paris Agreement or the Net-Zero Asset Owner Alliance's Target-Setting Protocol.

Bouchet and Shahyar argue that the above analysis leads naturally to four categories of investment strategies with the following aims and principal levers (see Table 2):

- *Sustainable*. Aim: to align the portfolio's constituents with one or more sustainable development goals, focusing on companies that 'do no harm' to environmental and social issues. Principal lever: exclusion, based on primary data.
- *Transition*. Aim: to transform companies with negative impacts into sustainable ones, using engagement on specific themes. Principal levers: exclusion thresholds and science-based transition plans, using both primary and secondary data.

[1579] https://www.sdi-aop.org/about/. SDIs are defined as those solutions that contribute to the UN Sustainable Goals.

- *Solutions*. Aim: to align a significant portion of the portfolio with specific theme solutions addressing environmental or social issues. Principal levers: dialogue with companies to reinforce and develop these solutions, and exclusion to ensure alignment with do-no-harm criteria.
- *Ethical*. Unlike the three preceding strategies, this category allows subjective preferences, such as religious or personal values, to influence investment criteria and targets.[1580]

**Table 2: Classification of sustainable investment strategies**

| | | Portfolio initial allocation | | | Portfolio management | | |
|---|---|---|---|---|---|---|---|
| **Strategy** | **Themes** | **Targeted companies** | **Negative screening** | **Weighting scheme** | **Shareholder engagement** | **Field building** | **'Output' metrics** |
| **Sustainable** | All | Companies whose behaviour and activities 'do no harm' to any SDGs | Covering all SDGs, based on revenues, physical metrics, controversies | Optimising risk and return under sustainability constraints:<br>● Negative screening | | Publication of exclusion list | Alignment with 'do no harm' criteria, dynamic review of controversies |
| **Transition** | Specific | Companies whose behaviour and activities 'do harm' to certain SDGs, but where change is possible | Companies not prioritised for engagement + Companies where engagement has failed | Optimising risk and return under sustainability constraints:<br>● Negative screening<br>● Min/max share of 'targeted transition companies' (sustainability segment) | Systematically engaging on issues relating to the specific theme chosen | Publication of targets, engagement outputs and exclusion list | Engagement results |
| **Solutions** | Specific | Companies whose activities contribute positively to specific SDGs | Covering all SDGs, based on revenues, physical metrics, controversies | Optimising risk and return under sustainability constraints:<br>● Negative screening<br>● Min/max share of 'positive contribution companies' (sustainability segment) | Focusing on engagement related to activities (strategy, investments) | | Share of 'positive contribution' investment |
| **Ethical** | All | Companies whose behaviour and activities are in line with ethical choices | Based on subjective preferences | Optimising risk and return under sustainability constraints:<br>● Negative screening | | | Respect of exclusion criteria |

Source: Vincent Bouchet and Shahyar Safaee (2024) Institutional equity portfolios: how can asset owners build coherent sustainable strategies?, *EDHEC Research Insights*, Summer 2024, p11.

Nick Stansbury, Carl Fredrik Pollack, and Emma Henningsson (2024) take a contrarian view: 'We believe the negative framing of the climate question and the slow transition progress of many companies have created a significant opportunity for investors'. They argue that 'the greatest climate impact – and potentially also some of the greatest returns –

[1580] There are other approaches to building sustainable portfolios. For example, Lazanas et al (2025) select a portfolio that minimizes the return variance, subject to a standard no-leverage constraint and an emission budget constraint that requires the weighted average carbon intensity (WACI) of companies included in the optimal portfolio not to exceed the net-zero compliant emissions budget (or target). The companies included from each sector of the economy will be selected from the peer group of companies in that sector. The optimal portfolio weight for a particular company is the standard minimum variance weight plus a term involving the product of the normalized target intensity change for the company's peer group (the excess of the net-zero compliant emissions of the peer group over the risk-weighted intensity average of the peer group, divided by the risk-weighted standard deviation of the intensity of companies in the peer group) and the emission intensity weighted z-score for the particular company (the excess of the emission intensity of each company included in the portfolio over the risk-weighted intensity average of the company's peer group, divided by the risk-weighted standard deviation of the intensity of companies in the peer group). If this product is positive, the optimal portfolio weight for a particular company will be higher than the standard minimum variance weight. See Equation (9) of Antonios Lazanas, Zarvan Khambatta, Yingjin Gan, Lingjuan Ma, and Niall Smith (2025) Building 'Net-Zero-Aligned' Portfolios, CFA Institute, 8 January; https://rpc.cfainstitute.org/research/reports/2025/building-net-zero-aligned-portfolios

can be sought by investing in those companies with high emissions or whose products have the greatest impact on other companies' emissions. Central to this approach is pro-active and profound company engagement; we believe in encouraging the companies to pull the levers necessary to target improved aggregate climate outcomes. The goal is to allocate more capital to drive the business opportunities the transition creates, while simultaneously driving down emissions over time'.[1581]

Another warning comes from a study by Samuel M. Hartzmark and Kelly Shue published in December 2023 called 'Counterproductive Impact Investing: The Impact Elasticity of Brown and Green Firms'.[1582] The authors argue that the dominant sustainable investing strategy in recent years involves directing capital towards green firms and away from brown firms, with the goal of facilitating a green economic transition by influencing the firms' costs of capital. However, this may be counterproductive, as it makes brown firms more brown without making green firms more green. The authors introduce a new measure called impact elasticity, which quantifies how a firm's emissions intensity responds to a change in its cost of capital. They examine the impact elasticities along with other financial and emissions data of US public companies from 2002 to 2020. Firms are then sorted into quintiles based on their emissions intensity, with the lowest representing brown firms and the highest representing green firms. With this data, the authors examine: the level and variability of firm emissions, the impact elasticities of brown and green firms, and the incentive effects of the dominant sustainable investing strategy.

The key finding from the study are:

- The average brown firm releases 261 times more emissions per unit of revenue than the average green firm. Additionally, the annual variability of emissions intensity for a brown firm is equal to the average level of emissions from 35 green firms combined.
- The impact elasticity of green firms is close to zero, whereas the impact elasticity of brown firms is large and negative. This means that brown firms substantially increase their emissions following an increase in their cost of capital, while green firms' emissions remain largely unchanged.
- Brown firms have different impact elasticities than green firms because they have the choice to invest in green projects, such as new pollution abatement technology, or brown projects, such as expanding existing high-emitting production. Green firms do not have such choice, as their projects all have relatively low emissions.
- Since green projects have higher up-front costs and relatively more backloaded cash flows than brown projects, an increase in a brown firm's cost of capital will make brown projects more attractive. Therefore, following an increase in their cost of

[1581] Nick Stansbury, Carl Fredrik Pollack, and Emma Henningsson (2024) Climate change:Inaction is not an option: Seeking to deliver an active approach to engagement and investing, LGIM and AP7; https://www.lgim.com/landg-assets/lgim/_document-library/climate-change-inaction-is-not-an-option-whitepaper-final.pdf

[1582] https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4359282

capital, brown firms deprioritize the green transition and emissions reductions, contrary to the goals of sustainable investing.

- Changes in environmental impact are often measured in the wrong units. Many green funds and ESG ratings mistakenly reward firms for a large percentage reduction of emissions rather than a large reduction in the level of emissions. For example, a green firm reducing its emissions by 100% is much less economically meaningful than a brown firm reducing its emissions by only 1% since the initial level of the brown firm's emissions intensity is substantially higher than the green firm's.
- Rather than avoiding brown industries, as many do not have suitable alternatives, sustainable investors should instead direct capital towards these brown industries and reward the relatively green or transitioning brown companies within these industries.

In short, the study finds that brown firms have a large and negative impact elasticity: they respond to increases in their cost of capital by increasing their emissions. In contrast, green firms have an impact elasticity of around zero: their emissions do not meaningfully change following a change in cost of capital.

A number of studies from asset managers and academics seek to address some issues about net-zero investing.

Valeria Dinershteyn and Guido Baltussen (2024), for example, argue that investors can achieve alignment with their net-zero commitment without significant active risk and without compromising their return objectives. They accept that many net-zero strategies have high levels of tracking error, but they explain this in terms of sub-optimal portfolio construction. Many climate-focused indexes are substantially underweight in sectors such as energy and utilities, but if sector volatility is high (e.g., due to sensitivity to economic events), the tracking error may also be elevated. They analyzed the impact of a carbon intensity reduction on a portfolio's active risk in the MSCI World Index universe. They calculated carbon intensity by dividing a company's carbon emissions by enterprise value including cash. Their research shows that investors can achieve significant reductions in carbon intensity with very little active risk. Specifically, just 0.5% of active risk in a portfolio is required to achieve an 80% reduction in carbon intensity. They point out that this scale of reduction is well ahead of the existing pathway for global carbon emission targets. Forward-looking measures of carbon risk, such as the MSCI Low Carbon Transition Score or the ISS Carbon Risk Rating, have a more material impact on active risk. For example, 1.0% of active risk allows for a 17% improvement in the MSCI Low Carbon Transition Score and a 27% improvement in the ISS Carbon Risk Rating.

Dinershteyn and Baltussen also counter a second misconception, namely that investors cannot gain meaningful exposure to factors such as value in a net zero portfolio. They found that it is possible to maintain the vast majority of targeted factor content while achieving carbon intensity reduction levels above 70%. Integration of forward looking measures have a bigger impact on factor content. They applied their representative set of climate change criteria to the MSCI World Index to see how it would impact a multi-factor

approach while allowing for up to 2% of active risk. They found that it is possible to retain over 85% of factor content while meeting significant sustainability goals.[1583]

Mathias Talmant (2024) also argues that it is possible to reconcile alpha with sustainability in impact investing. He says that 'Impact investing sits at the intersection of the Venn diagram. It is the only investment philosophy where the interests of all stakeholders (People, Planet, Prosperity) are aligned, in harmony and without compromise. The concept of Triple Bottom Line (or Triple P) challenges the perennial dilemma of impact versus return and implies that impact investing is not a zero-sum game. In other words, caring about sustainability does not mean ignoring fundamentals, but it does indeed limit the size of the investment universe as only the heart of the Venn diagram exhibits purity'. Using total returns by SFDR (Sustainable Finance Disclosure Regulation) classification as compiled by J.P. Morgan with Morningstar data in March 2024 and using Article 9 funds as a proxy for impact, Article 9 funds outperformed both Article 6 and Article 8 funds over a 5-year horizon, although they underperformed over shorter horizons. However, a high demand for impact funds leads to a price premium which can reduce returns, although Talmant concludes that this 'overlooks the nuanced landscape of sustainable investing, where untapped opportunities abound'. [1584]

Ha Do, Théo Le Guenedal, Meghna Bhaugeerutty, Kevin Alinejad, Skender Boughanmi, Aaron Mcdougall, Frédéric Lepetit, and Takaya Sekine (2025) examine the construction of share portfolios with climate-relevant metrics or signals, such as carbon footprint, carbon intensity and scope emissions.[1585] The aim is to assess the impact of introducing carbon or climate constraints and objectives in the portfolio construction process. The first step is to collect information that reflects the environmental impacts of a company's economic activity at the level of its financial securities. Each security issuer's activity implies carbon greenhouse gas emissions. By dividing these emissions by revenues or other production metrics, the carbon intensity of the company can be readily deduced. Further, an increasing number of companies report forward-looking carbon reduction targets and describe climate ambition plans in sustainability reports and regulatory reporting requirements, allowing the tracking of carbon emissions and disclosure over time. The second step is to develop more advanced and homogeneous harmonized risk metrics, e.g., measuring all scopes of carbon emissions; measuring the change in credit risk due to the introduction of a carbon tax; decarbonization in 2030 according to the setting of the target or the continuation of the current emission trend; or what a transition scenario (such as the Net Zero 2050 or Delayed 2°C) mean on a company's business. The last step is to integrate this set of signals in the optimal portfolio, along risk and expected return. The authors show that portfolios with

[1583] Valeria Dinershteyn and Guido Baltussen (2024) Addressing misconceptions with net-zero investing, Northern Trust Asset Management, November; https://hub.ipe.com/asset-manager/northern-trust-asset-management/addressing-misconceptions-with-net-zero-investing/10076602.supplierarticle

[1584] Mathias Talmant (2024) Reconciling Alpha with Sustainability in Impact Investing, Degroof Petercam Asset Management (DPAM), November; https://hub.ipe.com/asset-manager/degroof-petercam-asset-management/reconciling-alpha-with-sustainability-in-impact-investing/10076598.supplierarticle

[1585] Ha Do, Théo Le Guenedal, Meghna Bhaugeerutty, Kevin Alinejad, Skender Boughanmi, Aaron Mcdougall, Frédéric Lepetit, and Takaya Sekine (2025) Constructing Investment Portfolios with Climate-Relevant Metrics: a multifaceted problem, Aundi Investment Institute, April.

fewer Carbon Intensity Reduction ('spot decarbonization') constraints but higher Carbon Trend and Carbon Ambition constraints can be built and could have historically achieved similar performance. A key application of the approach is the construction of climate-aligned benchmarks, such as Paris-Aligned Benchmarks (PAB), which require dynamic portfolio adjustments to comply with stringent decarbonization pathways. These would help investors align their portfolios with transition objectives.

Andreas Brogger, Joren Koeter, and Mathijs van Dijk (2025) examine concentration risk in sustainable portfolios using a global sample of stocks from 47 countries between 1985-2023.[1586] They find that it takes around 750 stocks for portfolio volatility to converge to market volatility, in contrast with the 30-40 global stocks are sufficient to fully diversify idiosyncratic risk in standard portfolios. The second aspect of concentration risk they examine relates to FOMO (fear of missing out, leading to subsequent regret), the probability of missing out on the small fraction of top-performing stocks that drive the global equity premium. They find that that just 2.1% of stocks accounted for the entire global equity premium over the sample period (mainly the Magnificent 7[1587]). The consequence of this return skewness across stocks is that (very) concentrated portfolios are not only characterized by higher volatility, but also potentially by lower returns. It is possible to reduce volatility in small concentrated portfolios of 30-40 stocks by either careful stock selection based on correlations and volatilities or by imposing maximum weights for individual stocks and maintaining industry composition, but the resulting portfolios remain well short of complete diversification. It is even harder to alleviate FOMO risk in concentrated portfolios, since it is always possible that different portfolios do better ex post – resulting in FOMO. The authors conclude that investors considering concentrated portfolios should take both dimensions of concentration risk (incomplete diversification and FOMO on the next Magnificent 7) seriously as inputs to their decision-making.

### Climate betas

In 2023, international asset manager, Robeco, introduced 'climate beta', a risk metric which indicates how sensitive individual stocks are to a climate risk factor.[1588] Climate beta is based on the correlation of a stock's price with the climate risk factor and reflects the anticipated positive or negative response of the stock price to climate events.

Robeco's climate risk factor is based on a portfolio that takes long positions in a basket of stocks that contribute negatively to one or more climate-related SDGs ('polluting') and short positions in a basket of stocks that contribute positively to climate-related SDGs

[1586] Andreas Brogger, Joren Koeter, and Mathijs van Dijk (2025) FOMO in equity markets? Concentration risk in (sustainable) investing, Rotterdam School of Management, Erasmus University, June.
[1587] Apple, Microsoft, Amazon, Alphabet (Google's parent company), Meta (formerly Facebook), Nvidia, and Tesla.
[1588] https://www.robeco.com/en-uk/insights/2023/03/indices-insights-summer-summaries-introducing-climate-beta-a-complementary-climate-risk-metric; https://www.robeco.com/files/docm/docu-20241218-climate-beta-a-forward-looking-lens-on-transition-risk-hksg.pdf

('clean'). In other words, the climate risk factor tracks the difference in returns between polluting and clean companies. Specifically, Robeco calculates two long-short Climate Risk Factor Indices on a daily basis: the Robeco Developed Climate Risk LS Factor Index USD Total Return Index and the Robeco Emerging Climate Risk LS Factor Index USD Total Return Index. The returns on these indices represent the return differential between a long basket of stocks with poor climate SDG scores and a short basket of stocks with good climate SDG scores.

Robeco then estimates climate betas using a two-step procedure:

- Step 1: calculate the return on the climate risk factor that captures the return differential between companies with high climate risk exposure and companies with low climate risk exposure.
- Step 2: perform a weighted least squares (WLS) regression[1589] to estimate a stock's return sensitivity to changes in the climate risk factor:

$$R_t = \alpha + \beta_M MKT_t + \beta_{CB} CRF_t + \varepsilon_t$$

where $R_t$ is the return on the stock in month $t$ in excess of the risk-free rate, $\alpha$ is the risk-adjusted outperformance ('alpha'), $\beta_M$ is the stock's exposure to the market factor, $MKT_t$ is the return on the market factor in excess of the risk-free rate, $\beta_{CB}$ is the climate beta, $CRF_t$ is the return on the climate risk factor, and $\varepsilon_t$ is the residual.

This results in a metric, $\beta_{CB}$, that indicates whether a stock outperforms (negative climate beta) or underperforms (positive climate beta) when there is a positive shock to the climate risk factor. When the climate beta of a stock is zero, the price of the stock tends to be unresponsive to changes in the climate risk factor and, hence, insensitive to climate transition risk.

Robeco argues that 'climate beta is able to identify companies vulnerable to the low-carbon transition (climate laggards) and those expected to benefit from it (climate leaders). This is crucial information that generic emissions data does not provide. …More specifically, firms with a high climate beta tend to do well when the climate risk factor has a positive return, while the opposite is typically true for companies with a low climate beta. As a result, we expect stocks with high climate betas to be negatively affected by stricter climate policies, the transition to a low-carbon economy and innovations in green technologies. On the other hand, we expect stocks with low climate betas to benefit from a shift towards net-zero emissions. In general, we contend that climate beta picks up on a different dimension of climate risk compared to carbon emissions or carbon footprint data'. It concludes: 'Climate beta provides a forward-looking climate transition risk metric that provides unique insights above and beyond traditional carbon emissions data. By using climate beta,

[1589] Using WLS instead of ordinary least squares leads to regression estimates that assign greater weight on more recent information.

investors can better protect their investments against high climate transition risk and negative climate-related events'.

## Why global temperatures matter for asset pricing

Global temperatures matter for asset pricing since they affect expectations about future cash flows on financial assets and rate at which these cash flows are discounted. If climate change lowers expected economic and consumption growth, or increases uncertainty, investors will use a higher discount rate. This will influence asset prices, the risk-free rate and the equity risk premium (ERP).

In 'Climate risk in financial markets: a quantitative framework',[1590] Lionel Melin and Fangyuan Zhang use a new quantitative framework to demonstrate that 'climate change is an immediate macro-financial force that could reshape global markets'. They consider:

- Macroeconomic shifts: Rising temperatures slow structural economic growth through productivity declines and physical damages, while transition costs are likely to impose economic headwinds.
- Structural risks: Real risk-free rates are expected to decline as investors price in the economic drag from physical damage. Meanwhile, increased climate-driven uncertainty fuels market volatility and tail risks, especially for long-duration assets.
- Market revaluation: Under a 3°C warming scenario, the equity risk premium is projected to rise by 15–25%, permanently driving down valuation multiples for risky assets. Adding dented cash flows from economic damages to the picture should concern both long-term investors and policymakers.

The authors conclude: 'Portfolios with high exposure to long horizon cash flows (technology, infrastructure, utilities) are especially exposed. Also, sectors sensitive to policy and energy costs (utilities, materials, heavy industry) face significant repricing risk on potentially volatile transition pathways'.

## Constructing climate-risk hedge portfolios

Alekseev, Giglio, Maingi, Selgrad and Stroebel (2022) have proposed a quantity-based approach to constructing climate risk hedge portfolios.[1591] Climate-risk hedging strategies are becoming increasingly important for investors, but there are few financial instruments available that can directly hedge against these risks and historical stock prices may not contain enough information to estimate climate risk exposures. Accordingly, the authors introduce a new method to hedge climate risks by analyzing the trading patterns of mutual fund managers following a change in their beliefs on climate change. These patterns can

[1590] *EDHEC Research Insights*, Spring 2026.
[1591] Georgij Alekseev, Stefano Giglio, Quinn Maingi, Julia Selgrad and Johannes Stroebel (2022) A Quantity-Based Approach to Constructing Climate Risk Hedge Portfolios, Working Paper 30703, National Bureau Of Economic Research, December 2022; http://www.nber.org/papers/w30703

be used to determine the most relevant industries to buy and sell to hedge against negative climate news shocks.

The authors identify two primary triggers for a climate belief shift: an extreme heat event in the manager's region or changes in climate-related discussions in the fund's disclosure reports. Since these events are localized and only apply to a small subset of investors, they do not move stock prices. However, the quantity of stocks bought or sold by fund managers following these events contains information on how investor demand for assets in certain industries at the aggregate level shifts in response to heightened perceived climate risks. The authors quantify how fund managers respond to these events by analyzing the quarterly trading data of nearly 2,500 actively managed non-sector mutual funds in the US between 2010 and 2019.

The study finds that:

- Traditional climate hedging strategies based either on historical time-series data or economic reasoning, such as shorting companies vulnerable to stranded asset risks, are generally not correlated with negative climate news events, suggesting that climate risks are complex and difficult to hedge.
- The long-short quantity-based climate hedge portfolios constructed by the authors outperform the traditional approaches to hedging climate risks.
- This 'wisdom of the crowd' approach uncovers new insights about sector exposures to climate risks. The long-short hedge portfolio is long stocks in the automotive, semiconductor, insurance, and energy sectors and short stocks in the commercial and professional services, real estate, and retail sectors.
- Insurance stocks can surprisingly serve as a hedge to negative climate news, potentially due to expected increases in demand for insurance when climate risks are higher and the ability of insurers to reprice premiums annually.
- Similarly, auto stocks can serve as a hedge to negative climate news, potentially due to increase in demand for electric vehicles from households and firms hoping to reduce their carbon footprints.

Dirk Broeders, Daniel Dimitrov and Niek Verhoeven (2025) propose the introduction of climate-linked bonds to provide investors – including insurance companies and pension funds that are exposed to chronic losses resulting from climate change – with a hedge against long-term climate risks. The bonds adjust their payoffs based on climate variables, such as average temperature and greenhouse gas emissions. They would be issued by national governments and supranational organizations. The authors argue that the bonds would be 'pivotal in advancing towards a net-zero economy', since they would 'signal government commitment to climate action and incentivize stronger policies'. The price

differential between climate-linked bonds and nominal bonds would reflect market expectations of climate risks.[1592]

Another way to hedge climate risk is through insurance. Wenjun Zhu, Jinggong Zhang, Lysa Porth, and Ken Seng Tan (2025) explain how index insurance can be used to hedge climate and weather risk: 'Index insurance is a special type of financial contract whose payout is based exclusively on some pre-specified indices. For example, weather index insurance determines the claim payments based on future realizations of weather events determined from certain weather indices. The primary distinction between index insurance and traditional indemnity-based insurance lies in their payout mechanisms. In traditional insurance, payouts are directly tied to the actual losses experienced by policyholders. In contrast, index insurance bases its payouts on predefined indices, which should be built upon data that is both transparent and representative. This structure theoretically reduces information asymmetry issues, such as adverse selection and moral hazard, because the payout is not influenced by the specific losses of an individual policyholder but by the performance of the index. This attribute makes index insurance particularly appealing, as it addresses many of the limitations associated with conventional insurance models. …Furthermore, the adoption of advanced technologies, including satellite measurements and digitalization, has significantly reduced the costs associated with index insurance'. While index insurance has shown some growth in sectors like agriculture that are highly susceptible to weather-related risks, growth is still limited due to basis risk, the risk that the underlying indices and actual losses are mismatched. The authors argue that: 'While challenging to completely eliminate, basis risk can be mitigated through careful contract design. …Besides basis risk, ambiguity aversion, farmers' past insurance payout experiences, and insurance literacy, among others, are also influencing factors for index insurance demand'.[1593]

### The performance of ESG portfolios

Alves, Krüger and van Dijk (2025) analyzed the relationship between ESG ratings and stock returns over the period 2001-2020, across 16,000+ stocks in 48 countries and seven different ESG-rating providers.[1594] They found that ESG investing did not systematically affect investment performance during this period. They also found that: incorporating ESG ratings into investment strategies did not systematically come at the expense of financial returns; the prices of stocks with high ESG ratings were not consistently driven up by demand effects; and firms' cost of capital was not affected by ESG ratings. The authors argue that further research is needed to determine whether the lack of a relationship

[1592] Dirk Broeders, Daniel Dimitrov and Niek Verhoeven (2025) Climate-Linked Bonds, ECB Working Paper No. 2025/3011;https://ssrn.com/abstract=5091140 or http://dx.doi.org/10.2139/ssrn.5091140

[1593] Wenjun Zhu, Jinggong Zhang, Lysa Porth, and Ken Seng Tan (2025) Index-based Insurance Design for Climate and Weather Risk Management: A Review, in Hirbod Assa, Peng Liu and Simon Wang (eds.), *Quantitative Risk Management in Agricultural Business*, Springer Actuarial (chapter 2); https://doi.org/10.1007/978-3-031-80574-5_2

[1594] Rómulo Alves, Philipp Krüger, and Mathijs van Dijk (2025) 'Drawing Up the Bill: Are ESG Ratings Related to Stock Returns Around the World?', Working Paper, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4674146

between ESG ratings and stock returns is due to: the poor quality of ESG ratings, the less than pervasive prevalence of ESG preferences among investors, the challenges in distinguishing between short-term demand effects and long-term equilibrium effects, and/or other reasons.

Bruno and Goltz (2024) also find that sustainable investing did not yield higher returns than standard index funds over the period 2012-22.[1595]

A number of authors have investigated the performance of ESG portfolios using a common-factor asset pricing model[1596] which incorporates an ESG common factor. Pástor et al (2021)[1597] add ESG to a single-factor model, while Dobrick et al. (2025)[1598] add ESG to a Fama-French-Carhart four-factor model.[1599] The ESG factor in Dobrick et al. (op cit.) is defined as UMS (unsustainable minus sustainable), i.e., is long in 'unsustainable (brown)' stocks and short in 'sustainable (green) stocks'. In long-run equilibrium, the expected return on UMS is positive, since the expected return on unsustainable stocks should be larger than those of sustainable stocks. This is because investors are assumed to have a preference for green stocks, green stocks can be used to hedge climate risk, and green stocks have a resilience to ESG-related shocks, such as unexpected changes to climate-change-related regulation. This drives up the long-run equilibrium price of green stocks relative to brown stocks and drives down their long-run relative returns.[1600] However, during the transition period to equilibrium, when investor preferences are changing or when climate-related concerns are increasing, early investors in green stocks will capture the higher returns from the increase in their prices. The risk premium (or factor loading) on the ESG factor is therefore expected to be positive in equilibrium, but may be negative during the transition.

Dobrick et al. (op cit.) examined the ESG factor of three ESG-rating providers (ASSET4, LSE Refinitiv and Moody's Vigeo Eiris). Their data set consists of 4500 companies that have ESG ratings from all three providers over a sample period July 2007 - June 2020 for European companies and July 2012 - June 2020 for North American companies. For each provider, they construct ten decile portfolios with ascending scores for the UMS risk factor. If there are systematic risk components related to ESG, the risk premium is expected to be positive (negative) for the lowest (highest) scores and insignificant in between. This is what they find for each of the ESG-rating providers, suggesting that ESG should be incorporated into common-factor asset pricing models. However, the authors find the average ESG-factor risk premium is not significantly different from zero over the sample period,

[1595] Giovanni Bruno and Felix Goltz (2024) Sustainability alpha in the real world, *Scientific Beta, EDHEC Research Insights*, Winter.
[1596] This model tries to identify the factors that explain the common variation in stock returns over time.
[1597] Ľuboš Pástor, Robert F. Stambaugh, and Lucian A. Taylor (2021) Sustainable Investing in Equilibrium. *Journal of Financial Economics,* 142(2): 550–571; https://doi.org/10.1016/j.jfineco.2020.12.011
[1598] Juris Dobrick, Christian Klein and Bernhard Zwergel (2025) 'ESG as Risk Factor', *Journal of Asset Management*; https://doi.org/10.1057/s41260-024-00382-z
[1599] The four factors are market risk, size, book-to-market value, and momentum.
[1600] See and Pástor et al. (op cit.), Dobrick et al. (op cit.) and Bradford Cornell (2021) 'ESG Preferences, Risk and Return', *European Financial Management*, 27:12–19; DOI: 10.1111/eufm.12295

indicating that the average investor's return from holding green stocks was no different from the average investor's return from holding brown stocks. This is consistent with the findings of both Alves et al. (op cit.) and Bruno and Goltz (op cit.) above.

Greenfield et al. (2026) demonstrate that the integration of ESG factors into investments can improve earnings quality, reduce operational risk and increase enterprise value. Evan Gordon Greenfield, head of ESG in British Columbia Investment Management Corporation's private equity arm said: 'when treated as a financially-material operating discipline, ESG can drive measurable value creation in private equity. …ESG does not create value because it is ethical. It creates value when it is embedded in investment judgements, operating discipline and value-creation strategy'.[1601]

In April 2026, a survey conducted by UK-based wealth management and investment firm Rathbones found that nearly one third (31%) of UK investors preferred to have ethical or sustainable investments even if it reduced their financial returns. This preference was stronger (at 56%) in younger (those aged 30-44) investors that older investors (only 18% of 65–80-year-olds). Women had a slightly stronger preference than men (33% vs 29%). The preference was also strongly correlated with wealth: 42% of investors with more than £2.5m in assets, 36% with between £1m-£2m, 34% with between £500k-£1m, 27% with between £250k-£500k, and 31% with between £25k-£250k in assets. David Harrison, head of sustainability for Rathbones Asset Management, said: 'Ethical and sustainable strategies allow consumers to generate strong long-term risk adjusted returns without sacrificing their core values. We continue to see growing demand for sustainable investment strategies globally and expect this trend to remain consistent going forward. Structural issues such as the energy transition and water risk have not diminished. By accessing sustainable investment strategies, consumers are allocating more capital to help provide solutions to these systemic problems. While there may be shorter term performance trade-offs, we view the long-term opportunities as significant'.[1602]

### Exploiting climate-related share mispricing

Using 52 years of US stock data, Cuculiza et al (2025)[1603] found that firms with higher temperature sensitivity had lower future profitability and riskier corporate policies. These firms were also overpriced and earned lower average future returns as market participants were slow to correct the mispricing, suggesting the financial impact of rising temperatures was being underestimated. The sectors most sensitive to global temperature rises from climate change were agriculture and energy directly exposed to physical climate risks.

---

[1601] Evan Greenfield, Ashby Monk, and Dane Rook (2026) ESG Value Creation in Private Equity: From Rhetoric to Returns, 1 January; Available at SSRN: https://ssrn.com/abstract=6000614 or http://dx.doi.org/10.2139/ssrn.6000614; https://www.ipe.com/news/academic-paper-shows-financial-uplift-from-esg-in-private-equity-portfolios/10134503.article

[1602] https://www.investmentweek.co.uk/news/4528397/uk-investors-prioritise-sustainability-returns

[1603] Carina Cuculiza, Alok Kumar, Wei Xin and Chendi Zhang (2025) 'Temperature Sensitivity, Mispricing, and Predictable Returns', *Management Science*; https://doi.org/10.1287/mnsc.2023.00972

Local investors that were familiar with firms' regional conditions were more likely to price in temperature-related risks. However, nonlocal institutional investors allocated higher portfolio weights to firms with high temperature sensitivity, and sell-side equity analyst forecasts were less accurate for these firms.

Together, these results suggest that financial markets underreact to information about firm-level temperature sensitivity, and this generates predictable patterns in returns. A trading strategy that exploits this mispricing generated an annualized risk-adjusted return of 4.1% over the 1968–2020 period.

## The Sustainability Dividend and the value of climate patents

The Sustainability Dividend of a company is measured by it Sustainability ROI, the return on investment of its sustainability efforts.[1604] It is a key measure to attract investors in the company.

Sustainability ROI 'reflects the measurable benefits derived from corporate sustainable practices, including economic, environmental, and social gains. …[The] goal is to evaluate the full value (i.e., the overall worth or benefit) generated from these investments. Sustainability ROI differs from traditional ROI, which emphasizes measurable, short-term returns tied to monetary gains, by adopting a longer-term view and factoring in broader environmental, social and governance outcomes'.

Accurately measuring sustainability ROI can be challenging due to its multidimensional nature and intangible benefits: 'For example, a manufacturing company might reduce costs by improving energy efficiency and waste reduction, while a retail business could enhance its brand reputation by prioritizing ethical sourcing and reducing carbon emissions. Both approaches contribute to Sustainability ROI, but the value created may vary. Some factors, like energy costs, can be easily quantified, whereas others, such as positive brand association, might be more challenging to calculate and attribute. …To fully capture sustainability ROI, companies should account for both tangible (easily quantifiable) and intangible (non-physical, with harder-to-quantify monetary value) benefits, including those that may not be immediately obvious (hidden benefits)'. Currently, few companies are reporting their sustainability ROI.

Marie Brière, Murad Nuriyev and Sébastien Pouget (2025)[1605] analyze the effect of climate patents on a firm's market valuation. They investigate the relationship between Tobin's Q[1606] and the stock of patents across a range of climate technology categories. They find

[1604] The Sustainability Dividend: A Primer on Sustainability ROI; https://corpgov.law.harvard.edu/2025/01/04/the-sustainability-dividend-a-primer-on-sustainability-roi/

[1605] Marie Brière, Murad Nuriyev and Sébastien Pouget (2025) *Market Valuation of Climate Patents: What are the Most Valuable Innovations?*, Amundi Investment Institute, Working Paper 174, April; https://papers.ssrn.com/sol3/papers.cfm?abstract_id=5211154

[1606] Tobin's Q = Total market value of firm / Total asset value of firm. A Tobin's Q ratio of 1.0 indicates that the market value of the firm is equal to its asset value. A ratio greater than 1.0 suggests that the market

that, in general, investors do not value climate innovations. However, there were two notable exceptions. First, patents related to improving the efficiency of carbon-intensive technologies (i.e., carbon intensive climate innovation) show a positive correlation with a firm's Tobin's Q. Second, a select group of patents in non-carbon-intensive climate technologies, which contribute to both adaptation and mitigation efforts, are also positively valued. Their results show that a one standard deviation increase in the stock of patents relative to R&D expenses is associated with an increase between 0.5% and 1.5 % in Tobin's Q.

### Sustainable investing and the growth in artificial intelligence

Generative artificial intelligence will revolutionize knowledge work, potentially enhancing the productivity of those who are able to embrace the technology, while leading to job losses where the technology replaces specific types of jobs.[1607]

AI is heavily dependent on data centres – the physical infrastructure behind processes such as transmission, hosting, data processing and manipulation. These data centres use a massive amount of energy (and water), contributing to increasing power demands at a time when grids are already under strain.[1608] According to a report in *Nature*, AI-driven applications require 23-30 times the energy of standard digital processes. In Virginia, for example, data centres account for more than 25% of the state's electricity usage; similarly for financial hubs like London and Dublin.[1609] Miranda Beacham, head of UK responsible investment at Aegon Asset Management argues that these energy costs pose a significant challenge for responsible investing: 'With responsible investing becoming more nuanced, advisers must assess not just a company's ESG credentials, but also its exposure to rising energy costs. Advisers are urged to look beyond traditional ESG funds and consider funds focused on the energy transition. Renewable energy, grid infrastructure, and nuclear innovation are areas that could see long-term growth as AI's power needs expand. Advisers must also be prepared to explain the evolving regulatory environment and ensure that client investments align with their financial goals and ethical values'. [1610] The UK government has introduced the AI Opportunities Action Plan, which aims to balance AI growth with sustainability. The plan includes measures to enhance energy efficiency in data centres and

believes the firm is worth more than its asset value, potentially indicating overvaluation or future growth potential. A ratio less than 1.0 suggests under valuation, potentially indicating that the market believes the firm's assets are worth more than its market value, or that the market is not fully aware of the potential of the company's assets; https://www.investopedia.com/terms/q/qratio.asp

[1607] One UK-based research organization estimates that under a worst-case scenario, 8 million jobs could be lost in the UK; https://www.ippr.org/media-office/up-to-8-million-uk-jobs-at-risk-from-ai-unless-government-acts-finds-ippr

[1608] Data centres account for around 1% of global electricity consumption, and annual electricity consumption from data centres globally is about half of the electricity consumption from household IT appliances, like computers, phones and TVs; https://www.iea.org/commentaries/what-the-data-centre-and-ai-boom-could-mean-for-the-energy-sector

[1609] https://www.nature.com/articles/d41586-025-00616-z

[1610] https://www.professionaladviser.com/news/4410533/ais-energy-demands-pose-responsible-investing-challenge

promote the use of renewable energy sources to mitigate the environmental impact of AI expansion.[1611]

**Implications**

The findings in this subsection have implications for life expectancy (including that of pension scheme members), the assets in which pension funds invest, and the risk and return on those assets (including the risk of investing in what become stranded assets). These factors affect both the asset and liability side of pension fund balance sheets and also of insurers buying out pension fund assets and liabilities. There are other global developments that could affect life expectancy – some positively, others negatively.

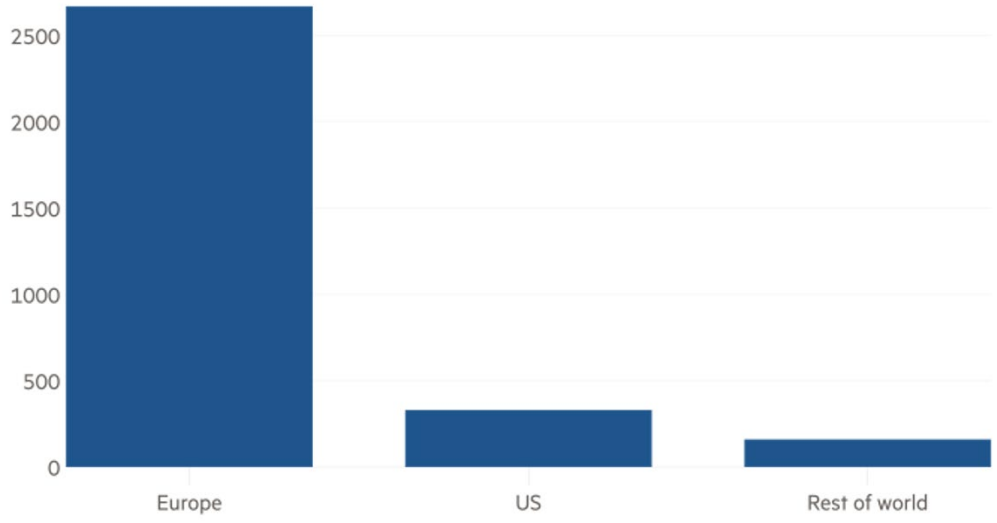
It is clear from this look into the future that longevity risk is likely to increase going forward – even the direction of the trend change in life expectancy will be more uncertain than it has been in recent decades. In addition, there is likely to be increasing uncertainty about the real level and volatility of the returns on the assets which pension funds and PRT providers need to hold to achieve their objectives. Technological developments and changing retirement patterns will also influence outcomes.

In addition, and despite all these initiatives, a report from the Oxford Sustainable Law Programme by Wetzer et al. (2024) argues that investors are 'flying blind' to the risk of 'increasingly impactful climate litigation and regulatory enforcement actions' that could hit companies with trillions of dollars in damages. The report counted 2,485 climate lawsuits filed globally against large corporate carbon emitters, with Chevron alone liable for up to $8.5trn if the climate lawsuits it faces are successful. The report recommends five ways for investors and regulators to assess climate-related legal risks: market-impact analysis; analysis using the social cost of carbon; attribution of climate change damages; estimating costs of accelerated climate mitigation, and qualitative analysis of legal, financial and scientific variables to predict legal action and its financial impact.[1612] Further, according to Will Martindale, former head of policy and research at the UN Principles for Responsible Investment, asset owners, such as pension funds, do not have the budget to meaningfully contribute to asset managers' stewardship efforts, such as policy engagement, in respect of sustainability challenges.[1613]

[1611] https://www.gov.uk/government/publications/ai-opportunities-action-plan/ai-opportunities-action-plan
[1612]Thom Wetzer , Rupert Stuart-Smith, and Arjuna Dibley (2024) Climate risk assessments must engage with the law: Legal actions determine the allocation and magnitude of climate-related financial risk exposures, *Science*, 383(6679): 152-154; 10.1126/science.adj0598
[1613] Will Martindale (2024) *Responsible Investment: An Insider's Account of What's Working, What's Not and Where Next*, London: Palgrave Macmillan.

Finally, Figure 21 shows that the majority of sustainable funds are based in Europe.[1614] Around 9,000 of the EU's 27,000 funds (which are mainly domiciled in Ireland and Luxembourg) are classified as sustainability-focused.[1615]

**Figure 21: Assets under management by sustainable funds, March 2025 ($bn)**




Source: Morningstar; https://www.ft.com/content/142eb9ee-7b20-4308-9d13-38613af58ea1

**Longevity 19**

As with the previous conferences, *Longevity 19 (L19)* consisted of both academic papers and more practical and policy-oriented presentations. There were four plenary sessions and the following keynote speakers contributed to these sessions:

- Plenary Session 1: Hot topics in longevity
    - Guy Coughlan (Chief Operating Officer at Clota Värde and member of the Advisory Board at Longevity Solutions) opened the conference with a presentation entitled 'Living longer, planning smarter: Harnessing longevity Indices to manage individual, institutional and systemic risk'.

      An extreme increase in longevity can significantly impact: individuals (who face idiosyncratic longevity risk (population longevity risk + idiosyncratic deviation risk) which could lead to old age poverty if they have insufficient savings); institutions (which face diversified longevity risk (population

[1614] The Morningstar data comprises funds that claim to focus on sustainability, impact or environmental, social and governance factors.
[1615] https://funds-europe.com/sustainability-funds-cross-e6tn-shows-maples-analysis/

longevity risk + subpopulation deviation risk) which could lead to financial distress or insolvency if they have insufficient capital and reserves); and the economy (which faces systemic longevity risk[1616] which could impair parts of the financial system and have serious negative consequences for the real economy).

In terms of individuals, longevity risk can be partially mitigated with two standard solutions:

- Income drawdown strategy. At retirement, implement a lifetime income strategy based on life expectancy. But the risk at retirement is that income may be lower than expected because: the investment fund size is lower than expected and/or the drawdown rate percentage is lower than expected. Significant risks are crystallized at retirement; there are only moderate risks post-retirement.
- Annuity purchase. At retirement, the individual buys a guaranteed lifetime income from an insurer with their savings pot. The annuity pays a percentage of fund size for life. The risk at retirement is that the income is be lower than expected because the investment fund size is lower than expected and/or the annuity rate is lower than expected. Significant risks are crystallized at retirement.

It is possible to protect against lower retirement income by hedging the longevity risk in the accumulation stage until retirement, either with respect to the drawdown rate or the annuity rate. The hedge would be a longevity index hedge, since drawdown rates and annuity rates are generally based on population life expectancy at the retirement date. This would provide some longevity risk mitigation for defined contribution pensions.

In terms of institutions, the impact on institutions can be mitigated by transferring longevity risk to investors. However, the population longevity risk cannot be eliminated, but it can be shared across different institutions which hold capital to support risk-taking. Longevity risk sharing has been implemented using longevity swaps, bulk annuity contracts (pension buy-outs and buy-ins), and longevity index hedges. The main kinds of institutions that would benefit from using longevity index hedges would be insurers and pension plans that retain most of their longevity risk over the medium-to-long term, pension plans that intend to do a buy-out or longevity swap in the future, and reinsurers of longevity risk. These institutions have a number of objectives. The first is to reduce but not eliminate longevity

[1616] Longevity is a 'long-term systemic risk'. *The Limits of Market-Based Risk Transfer and Implications for Managing Systemic Risks*, International Monetary Fund, Working Paper WP/06/217, 2006; https://www.imf.org/external/pubs/ft/wp/2006/wp06217.pdf

risk, with the aim of holding some diversified longevity risk over the medium term but not all of it. The second is to manage the longevity risk of deferreds, with the aim of either reducing the exposure to long-duration longevity risk or to eliminate longevity risk in the future when pensions/annuities are in payment.

In terms of the economy, an extreme longevity event could crystallize systemic risk across the financial system.[1617] The IMF's *Global Financial Stability Report* (2012) said that: 'Threats to financial stability from longevity risk derive from at least two major sources. One is the threats to fiscal sustainability as a result of large longevity exposures of government. …A second factor is possible threats to the solvency of private financial and corporate institutions exposed to longevity risk'. The IMF estimated that 'If everyone in 2050 lived just three years longer than now expected, society would need extra resources equal to 1 to 2 percent of GDP per year'. To fully fund these additional liabilities could cost 50% of GDP for advanced economies and 25% of GDP for emerging economies.[1618] Defined benefit pension liabilities, in particular, reflect a huge longevity exposure. To illustrate, in the UK in 2023, corporate sector DB pension liabilities were valued at £1.3trn. Government total DB liabilities were £9trn, comprising £2.9trn in respect of public sector pension plans and £6.1trn in state/social security pensions. This total of £10.3trn compares with UK GDP of £2.3trn. Longevity risk could trigger a systemic risk event across the financial system which could lead to disruption of the financial system and the real economy. This is because of the high level of economic interconnectivity between financial institutions (DB pension plans, insurers, reinsurers, investors, and banks), governments, businesses, and individuals (via their roles as employees, consumers, savers, and borrowers).

Longevity index hedges can help mitigate systemic risk by helping to spread longevity risk more widely and by enabling institutions with a lot of longevity risk to easily transfer a significant fraction of it.

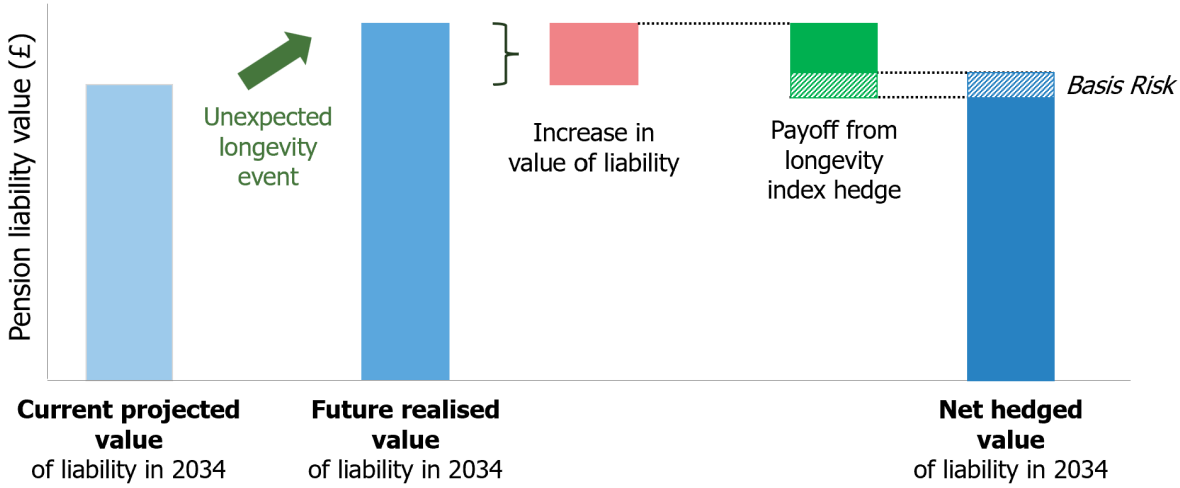
Longevity index hedges are different from traditional longevity swaps and can be preferred in certain situations. They have the benefits of being operationally simple, involve no transfer of personal data, and have a flexible structure. They have different characteristics from a traditional longevity swap: they hedge the *value* of the pension cash flows at a future date, not the *cash flows* themselves; they index a standard population of

[1617] International Monetary Fund (2006) *The Limits of Market-Based Risk Transfer and Implications for Managing Systemic Risks*, Working Paper WP/06/217, 2006; https://www.imf.org/external/pubs/ft/wp/2006/wp06217.pdf

[1618] International Monetary Fund (2012) *Global Financial Stability Report*, International Monetary Fund, 2012; https://www.imf.org/external/pubs/ft/gfsr/2012/01/

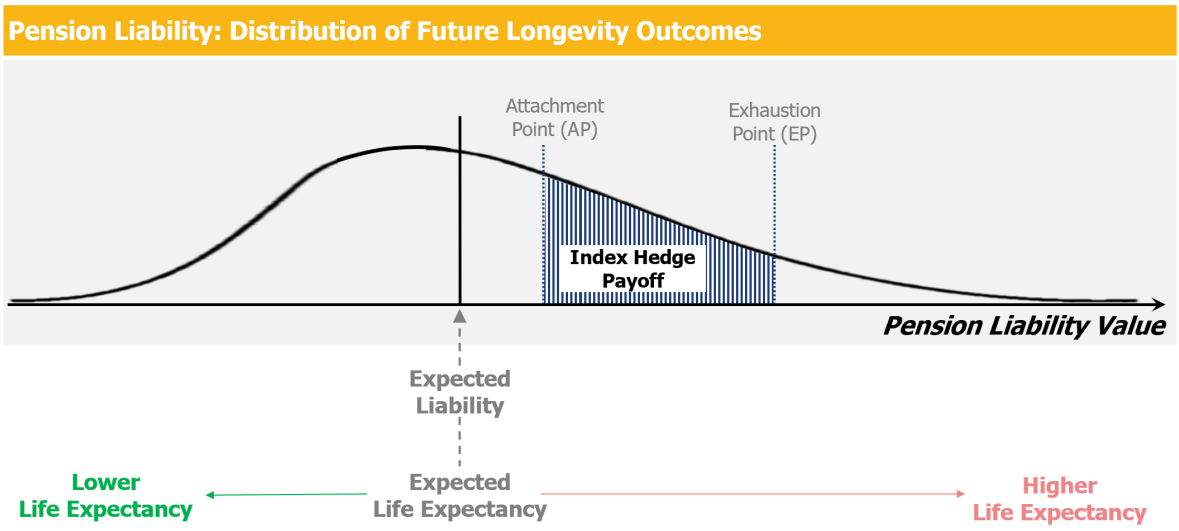
lives, not the actual lives in a pension plan; and they have medium maturity (e.g., 7-10 years), not to run-off or a very long maturity, so need to be rolled over on maturity. These hedges involve 'basis risk' for value, demographic and structuring reasons. They will therefore not be 'perfect'. Nevertheless, longevity index hedges can, if appropriately structured and calibrated, be 'highly (>85%) effective' in reducing volatility and likely more effective in the case of a large longevity event.

The longevity index hedge protects the future value of liabilities against changes in forward life expectancy:




The payoff from the index hedge offsets the unexpected increase in liabilities.

Longevity index hedges can be customized to provide protection where it is most needed and at lowest cost, through the appropriate setting of the attachment point (AP) and the exhaustion point (EP) which determine the minimum and maximum index hedge payoff:




An appropriately structured and calibrated longevity index hedge can be used against changes in forward life expectancy to protect the future:

- value of pension / annuity liabilities
- price for a traditional longevity swap
- cost of a pension buy-out
- annuity rate for individuals
- drawdown rate for individuals.

Longevity index hedges can help manage longevity risk for individuals and institutions and can help mitigate systemic risk. But they do require a mindset change, especially by the regulator. This is because they can be 'highly-effective' hedges , although not 'perfect' hedges (as with insurance-based indemnity solutions).

- Marine Habart (AXA) and Alexandre Boumezoued (Milliman) gave a presentation entitled 'The new actuarial challenges when setting mortality/longevity assumptions: from leveraging on artificial intelligence… to managing the IFRS17 new accounting framework'.

  Setting mortality/longevity assumptions lies at the intersection of actuarial science, demography... and now financial reporting under the new IFRS17 accounting standard.

  This new framework requires more granular assumptions that directly influence financial disclosures, affecting key metrics like (1) the technical provisions, (2) the Contractual Service Margin (CSM) and (3) operating variance. Actuaries must now also collaborate with accountants to manage the impact of changing assumptions on external financial reporting.

They face challenges such as data quality, assumption accuracy, managing volatility, and effectively communicating these complex topics to non-expert stakeholders (e.g., management, investors). Leveraging new technologies like artificial intelligence (AI) and conducting robust scenario analyses are essential to enhancing the accuracy of assumptions and ensuring stability.

Advancements in AI and natural language processing (NLP) indeed now enable the robust processing of unstructured data for sentiment analysis, which has practical applications in various societal contexts, including mortality prediction. Despite past challenges with big data exemplified by Google Flu Trends, recent studies show that sentiment analysis can predict outbreaks in real time, by processing news, or assess individual risks, like 30-day mortality in sepsis patients, by analyzing unstructured text data from nursing notes. These studies highlight the potential of sentiment analysis in improving early trend detection and mortality predictions by incorporating subjective information from unstructured data.

- Professor Sune Lehmann (Technical University of Denmark and University of Copenhagen) gave a presentation entitled 'life2vec: Predicting personality, death, emigration, and other life-events from embeddings of registry data'. He began by pointing out that LLMs (large language models) have been eating the world lately. But what is it that they do? The whole idea is about turning language into math and drawing on the structural similarity between natural language sentences and human lives.

  As his illustration of the concept, he discussed a recent co-authored study 'Using sequences of life-events to predict human lives'.[1619] The study represented human lives in a way that shares structural similarity to language, and the authors exploit this similarity to adapt NLP techniques to examine the evolution and predictability of human lives based on detailed event sequences. They do this by drawing on a comprehensive registry dataset, which is available for Denmark across several years, and that includes information about life-events related to health, education, occupation, income, address and working hours, recorded with day-to-day resolution. They create embeddings of life-events in a single vector space, showing that this embedding space is robust and highly structured. The authors' models allow them to predict diverse outcomes ranging from early mortality to personality nuances, outperforming state-of-the-art models by a wide margin. Using methods for interpreting deep learning models, they probe the algorithm to understand the factors that enable their predictions.

[1619] Germans Savcisens, Tina Eliassi-Rad, Lars Kai Hansen, Laust Hvas Mortensen, Lau Lilleholt, Anna Rogers, Ingo Zettler and Sune Lehmann (2024) 'Using sequences of life-events to predict human lives', *Nature Computational Science,* 4: 43–56.

Their framework allows researchers to discover potential mechanisms that impact life outcomes as well as the associated possibilities for personalized interventions.

- Alexandre Boumezoued and Tinhinane Talbi (both from Milliman) gave a presentation entitled 'Quantifying the unseen: Dissecting the effects of air pollution on mortality'.

  Air pollution significantly impacts human health and mortality worldwide. The presentation examined the effects of air pollution on mortality and highlights the challenges in modeling its impact and the need for advanced approaches.

  Climate events (e.g., air pollution, frequent natural catastrophes, reduction of food and water supply, changes in vector ecology, environmental degradation and climate migrations, extreme cold snaps, and frequent extreme heat) impact health and mortality in different ways, that is not always easy to model. Direct deaths can be modelled. But can the impact on disease prevalence leading to indirect deaths be modelled?

  Air pollution has a complex relationship with climate change, with an important impact on health. As defined by WHO, 'Air pollution is contamination of the indoor or outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere'. Climate change impacts atmospheric chemistry, meteorology (temperature, pressure, humidity) and produces direct emissions (dust, fires). It has a number of potential consequences for health: cardiovascular events, respiratory diseases, gastrointestinal diseases, cancers, urinary conditions, allergies, diabetes, and autoimmune diseases.

  However, using historical patterns to model mortality rates from air pollution may not be relevant: fluctuations in pollutant levels do not necessarily seem to be reflected in a reduction in mortality due to air pollution. Moreover, uncertainty about air pollution evolution makes the projections more difficult.

  In attempting to derive the relationship between pollutant concentration change and mortality change, there are two principal approaches:

  - Indirect approach: Establishes scenarios of disease prevalence under different air pollution levels: identification of impacted diseases; study of the prevalence of these diseases (i.e., morbidity climate scenarios); and the mortality rate of the exposed population.
  - Direct approach: Use concentration response functions (CRFs) to link mortality to changes in air pollutant concentrations:

$$\ln(y) = \alpha + \beta C$$

where

$y$ = mortality rate
$\alpha$ = vector of independent variables
$\beta$ = risk of health effect due to one-unit change in air pollutant concentration
$C$ = air pollutant concentration.

The projected impact of ozone on mortality in metropolitan France in 2022 (aged 65+):

| Temperature C° | Baseline situation | 1 | 1.5 | 2 | 3 |
|---|---|---|---|---|---|
| Ozone ($\mu/m^3$) | – | 2.8 | 4.2 | 5.6 | 8.4 |
| Excess deaths | – | 8,378 | 15,619 | 22,760 | 36,747 |
| Additional mortality rate | – | 0.060% | 0.112% | 0.164% | 0.264% |

- Plenary Session 2: Advances in the longevity risk transfer market
    - Douglas Anderson (founder of Club Vita) opened the second plenary session with a presentation entitled 'The state of the market for longevity risk transfer'. He began by discussing the key drivers of the growing market. Demand from risk cedants was driven by: higher interest rates (make corporate pension derisking affordable (c$100bn a year globally); an aging population (converting DC pots into lifetime income); and the cost-of-living crisis (resulting in equity-release mortgages sales of c.£10bn a year in the UK and cashing-in life insurance at c.$5bn a year in the US). Supply from risk takers was increasing due to a growing number of direct writers, helped by capital from reinsurance (private equity investment channeled through reinsurance 'sidecars' and 'whole of market' funded reinsurers). However, regulators were discouraging primary insurers' concentration of credit risk in reinsurers.

      Global pension risk transfers have been stable at $100bn since 2019, mainly due to declining yields raising liability values which has impeded market growth. However, bond yields have recovered to pre-financial crisis levels, so PRT markets really were now booming. In terms of other other longevity-linked products, annuities are c.30% cheaper than in 2020 and demand is increasing in the UK, although the value of equity release mortgages sales to the over 60s fell 48% between 2022 and 2023.

Overall, deal writing capacity has increased. There were now 11 primary insurers in UK competing for around $60bn a year and a total of 21 primary insurers in US competing for around $50bn a year.

US longevity reinsurance is becoming a thing. The main causes were: increased use of funded reinsurance (with a desire to focus on certainty of returns for investors); the importance of primary insurers' credit ratings for winning PRT deals; and greater awareness of longevity trend risk by primary insurers' chief actuaries. And, very recently, US plan sponsors have been permitted to buy longevity reinsurance via a captive (as in UK).

Finally, Douglas discussed the emergence of a new discipline called Longevity Science. It is at the intersection of: biological and medical sciences (biology, biochemistry, epidemiology, genetics, neuroscience, regenerative medicine, pharmacology, immunology, nutrition science); technological and engineering disciplines (biotechnology, AI, bioinformatics, biomedical engineering, nanotechnology, robotics); economic, legal and policy disciplines (economics, actuarial science, public policy, bioethics, medical law) and social and behavioral sciences (public health, sociology, psychology, demography, anthropology, social gerontology, behavioral economics).[1620]

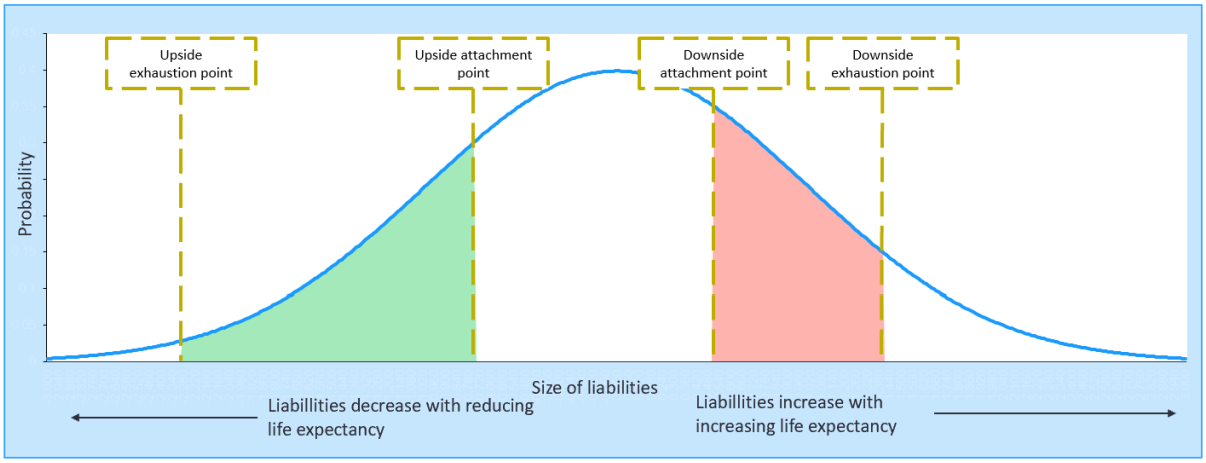
- Paul Kitson (EY) presented on 'Using longevity risk hedging techniques to enhance retirement outcomes for members of defined contribution pension plans'. A key theme was protection against lower retirement income by hedging the longevity risk in the accumulation stage until retirement. In line with Guy Coughlan's suggestions in the first plenary session, it is desirable to hedge the longevity risk associated with the annuity rate and the drawdown rate. This can be achieved with a longevity index hedge, since drawdown rates and annuity rates are generally based on population life expectancy at the retirement date.

  But there are challenges. First, individual pension pots in the UK are too small to hedge on an individual basis. However, the risk can be pooled into retirement age / target date fund vintages – this is what is done with the investments of the scheme. Second, we do not know whether the member will take an annuity or enter drawdown. But this does not really matter, since the payoff need is in the same direction. Third, the general population may not match individual life expectancy. Here, we need a mindset shift – it is a 'value' payoff – not full indemnity protection. Fourth, members will

[1620] Geneva College of Longevity Science.

not understand it. The solution is to include it in the default investment strategy.

Hedging could also help in decumulation. All options at retirement are exposed to longevity risk: with drawdown, funds could be needed for longer than anticipated; delaying the annuity purchase until age 75 could cost more than anticipated (i.e., the annuity is exposed to longevity risk during the drawdown period); the common assumption made by providers and financial advisers that the retirement period lasts 30 years (since the retiree is not expected to live beyond 95) could well turn out to be wrong: retirees are increasingly likely to need income for longer. Many providers are using older age target date funds with an income dividend as a decumulation vehicle. For example, a fund could: pay an until age 75 and then an annuity is purchased; or it pays an income until age 95 and then pays a lump sum to cover later life costs. Longevity protection could be structured to pay more if life expectancy has increased by the time the member reaches age 75 or 95. In short, longevity protection is valuable throughout the DC lifecycle. The key is to protect the red 'danger zone':




The green area is the upside which the scheme is willing to give up to offset the downside risk (red area). By structuring this to be approximately equal in area to the red area, the cost of the arrangement can be minimized.

The white area is where the scheme retains longevity risk (for portion not covered by existing longevity swap). The scheme still stands to benefit from some upside should longevity fall. The scheme also retains some downside exposure in the worst-case scenarios.

The red area is the key downside risk which the scheme wishes to hedge. Doing so removes the longevity risk in the likely downside scenarios, where the risk is cheaper to insure, without seeking to mitigate the most severe outcomes.

Longevity hedging is also possible in the case of a collective DC (CDC) scheme. Under a CDC scheme, risks are pooled and smoothed over time. The case for longevity hedging makes a lot of sense – especially where sections of the risk can be removed – the potential to remove the danger zone. Upside can be used to fund downside exposure so there is minimal drag on returns. The hedge can be structured to provide greater support while the CDC scheme builds up its own resources.

- Leendert van Gastel from the EU's pension and insurance regulator (EIOPA) spoke from the 'Perspective of the regulator'. EIOPA is responsible for enforcing: the Solvency II Directive (2009) on insurers and reinsurers; and the IORP (Institutions for Occupational Retirement Provision) II Directive (2016) on pension schemes. EU Member States shall ensure that national supervisory authorities take duly into account its guidelines and recommendations. The main objectives of insurance and reinsurance regulation and supervision are: the adequate protection of policy holders and beneficiaries; and financial stability and fair and stable markets. Member States should also protect workers from old-age poverty and promote supplementary pension schemes linked to employment contracts as additional coverage to public pensions.

  Leendert then pointed out that EU pension fund reinsurance against longevity risk would need about 60% of all the capital of reinsurers. He supported the engagement of capital markets in providing additional longevity hedging via sidecars (set up through SPVs), longevity index contracts, *q*-bonds / survivor bonds, and public private partnerships. However, reinsurers still have a central role, given their expertise in longevity risk modeling and capital markets. Nevertheless, information asymmetry may hamper developments, so there needs to be cooperation with investors and the public sector.

  Supervisory concerns centre around: concentration risk (only a limited number of reinsurers have appetite for longevity risk, and the natural hedge with mortality risk has basis risk) and funded reinsurance (the key problems are regulatory arbitrage and retrocession, opaque asset risk, and the inability of supervision to take away credit risk).

  Leendert finished by summarising the regulatory treatment of longevity risk in the EU. First is the 'standard formula' where risk is measured by one simple standard scenario. It is not a risk model, it is calibrated on EU data, it does not allow insurer-specific mortality data, and there is no capital relief when basis risk is present. Second is the 'internal model'. This involves VaR at the 1-year horizon, has no upfront restrictions, may match a sophisticated pricing model (involving a longevity index, survivor bonds, etc), and requires approval by a Member State national supervisor. But it does not need approval by EIOPA.

- Plenary Session 3: Longevity issues in the Netherlands, the US, the UK and Australia

  - Cara Dowell (RGA) gave a presentation entitled 'Location and longevity: Deciphering mortality through the lens of US and Dutch postcodes'. She began by pointing out that the Dutch and US pension markets are increasing

rapidly. This has generated a growing need for precision: insurers need a more precise set of mortality assumptions to stay competitive. But the quantity of data provided by plan sponsors is limited and not improving, so insurers must find ways to supplement the plan data provided.

What can be used to predict mortality rates? From a life insurance perspective, the following are relevant in order of significance: age, gender, health records, tobacco history, blood and fluid tests, family health history, profession, income, address of residence, cognitive testing, prescription history, marital status, physical activity, motor vehicle history, credit history and type of product. From a longevity perspective, the following are relevant in order of significance: age, gender, postcode, form of payment, benefit amount and pensioner/dependant status.

From the postcode, we can learn the following: number of individuals with disease X, credit history, smoking propensity, number of grocery stores, proximity to hospital, common lifestyle, and blue/white collar mix.

But aren't post codes too granular to use for assumptions? Not if you cluster them! Individually, post codes at the zip+4 (average number of US households = 4) or PC6 (average number of US households = 18) level do not have enough experience to be credible. Cara recognizes that people in different post codes can have similar mortality. Purchasing cluster information from data vendors is an option.

There are two key ways of clustering postcodes. The first uses a clustering technique: start with a factor variable with many levels, determine an optimal number of grouped-levels that retains high predictive power and limits unnecessary complexity in the model. The second uses postcode attributes in a general linear model (GLM) with data that maps attributes to every postcode. There are, however, challenges with using mapped postcode attributes: some attributes may be modeled rather than factual data; it can be difficult to find postcode attributes that make sense actuarially; there are lots of correlations going on; not all attributes are available for all postcodes, so there are missing data; users need considerable experience in order to start using postcode attributes; and not every actuarial system can handle this level of granularity. But without postcode attributes in the GLM, you are leaving precision on the table.

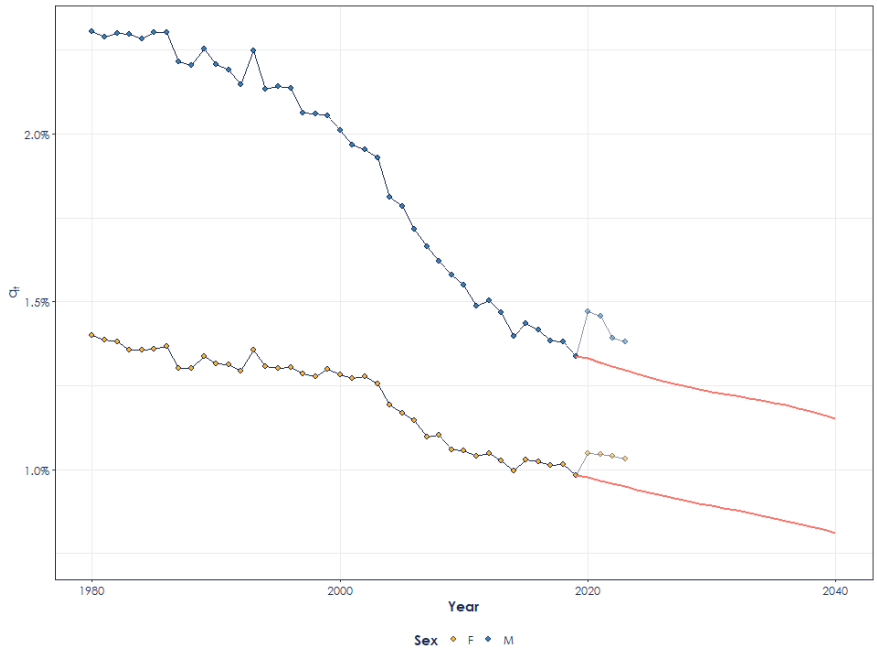
Cara's analysis found that the postcode to be more or less predictive in the Netherlands, compared with the US. Suggested reasons are: the US may have greater economic inequality; Dutch postcodes could be less segregated; the Dutch have a universal healthcare system unlike the US; DB plan participant demographics; and the quality of postcode data.

In summary, postcode attributes can serve as a proxy for other variables that are strongly predictive of mortality, thereby increasing a mortality model's precision; great care should be used when choosing which postcode attributes to include in a mortality model; and the success of a postcode model can be dependent upon the specifics of the pensioner population as well as the quality of data available.

- Andrew Hunt (Head of Mortality Trend Research, Pacific Life Re) spoke on the topic of 'Post-pandemic mortality in the Netherlands and the UK'. The COVID-19 pandemic of 2020/21 is a discontinuity in mortality, separating the data into distinct eras before, during and after the pandemic. This makes modelling difficult – almost all the data for setting trends is pre-pandemic but is being used to forecast a post-pandemic world. Reliance on judgement and expert opinion is slowly giving way to more quantitative modelling, which will only increase as the volume of post-pandemic data grows. But navigating the transition is difficult – we can't just skip those two years and hope to pick up where we left off.

  Looking at COVID-19 in the Netherlands, according to WHO, there have been c.23k COVID-19 deaths from 8.6m cases in the Netherlands, mostly occurring over 2020 and 2021. However, there have been c.68k more deaths in the Netherlands since 2020, compared to an extrapolation of the 2015-2019 pre-pandemic trends. Excess mortality has continued throughout 2022 and 2023, even as reported COVID deaths have dropped off. Clearly, there is more happening than just COVID-19. This represents a clean break in the path of (age-standardised) mortality in the Netherlands. The question we have been dealing with for the past four years is how to deal with this for projections.

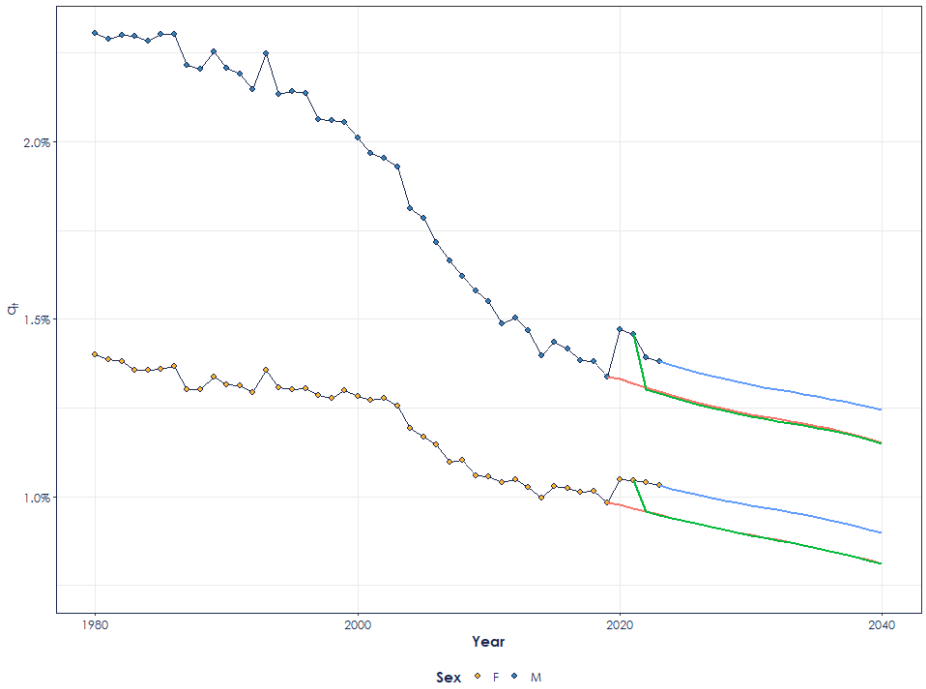
  Imagine you have developed a baseline projection using pre-pandemic data up to 2019 that you were happy with:




Data for 2020 and 2021 is clearly exceptional and so tend not to be used in projection. You can either exclude from the dataset or use indicators to control for excess during those years:




The more interesting case in when data for 2022 and 2023 (and onwards) is added. This data is somewhat predictive. We want it in the model to inform the level of post-pandemic mortality. However, it is unlikely that the excess mortality in recent years will persist indefinitely:



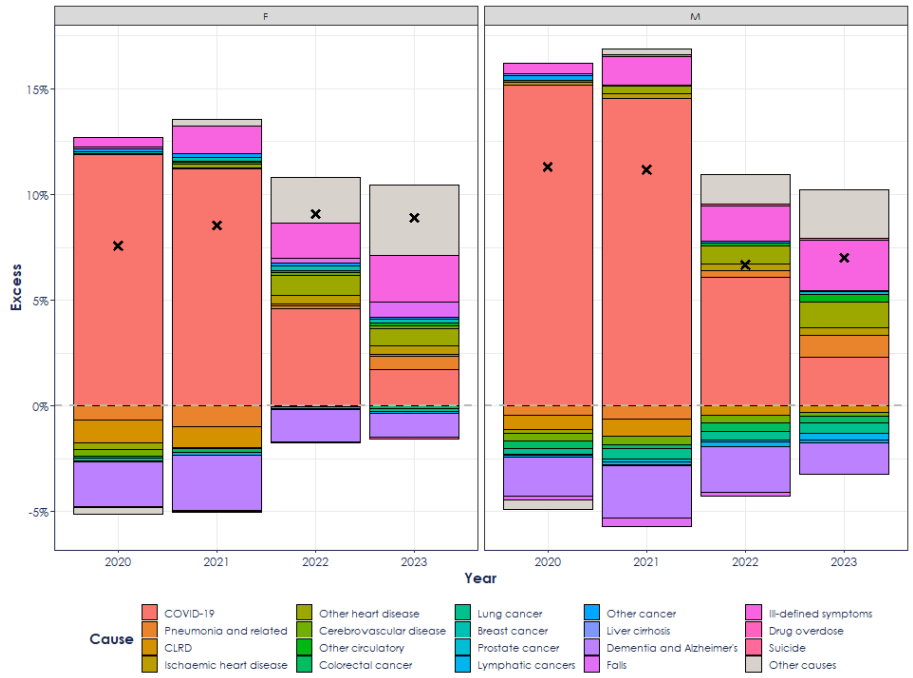

In order to make progress with our understanding of excess mortality, we need to: understand the drivers of excess mortality in 2022 and 2023; make judgements around how long these will persist into the future; and build these judgements into the model in a way that will be robust to future updates of the data. This will require analysis of the data but also bringing in other viewpoints and perspectives to go beyond what the data can tell us at present. Cause of death is one natural framework to address this, since it links directly to the data being used and will update in future.

Andrew proposed a simple cause-of-death model which fits and projects the proportions of deaths from different causes directly:

$$\ln\left(\frac{p_{x,t,c}}{p_{x,t,C}}\right) = \alpha_{x,c} + \beta_{x,c}(t - \bar{t})$$

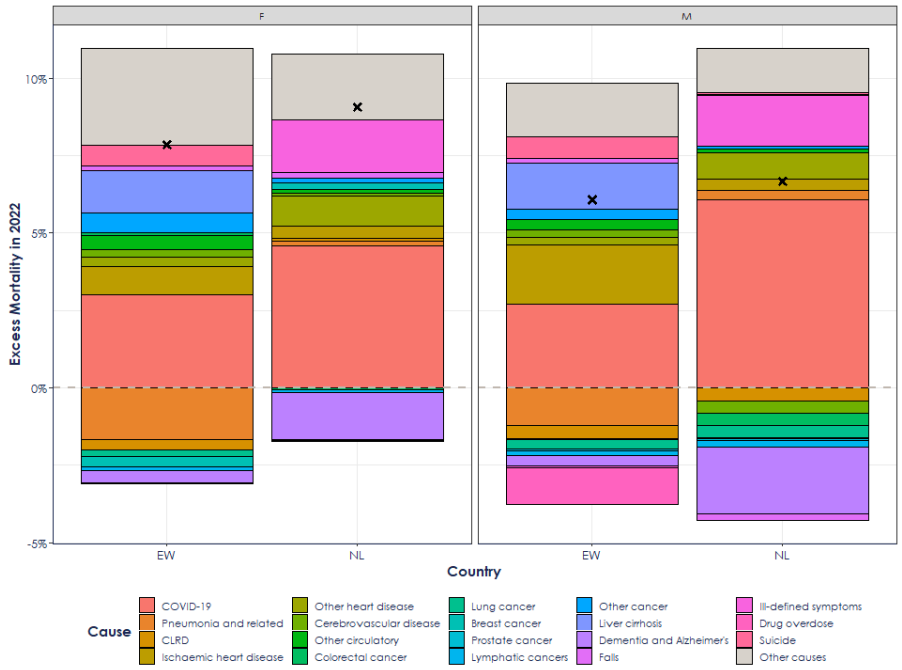
This means we can directly pull apart the pre-pandemic baseline mortality rates by cause and compare with actual data.

Age-standardised excess mortality by cause in the Netherlands shows that a large number of different causes contributed to higher mortality during and after the pandemic:




Overall, excess mortality has dropped slightly, but not massively. However, its composition has changed a lot. Excess mortality was dominated by COVID-19 during the pandemic. This reduced in 2022 and again in 2023, but remains a significant cause of death. Lower dementia mortality has partially offset COVID-19, although this has diminished over time. The lack of 'flu outbreaks during 2020 and 2021 also contributed to offsetting the COVID excess, but this reversed in 2023. Circulatory conditions, especially heart diseases were higher than expected in 2022 and 2023. One of the largest contributors to excess mortality however is 'ill-defined and unknown causes of death': it is unclear exactly what is driving this.

Turning to England & Wales, excess mortality in 2022 was very similar to the Netherlands:




However, the drivers look to be very different. The Netherlands had higher mortality from COVID-19 directly than England & Wales in 2022. The offset coming from lower dementia mortality in the Netherlands is not seen in England & Wales. However, the UK continued to enjoy relatively little influenza in 2022. England & Wales however had a larger excess mortality from circulatory conditions, especially ischaemic heart disease than the Netherlands did. We do not see the same increase in 'ill-defined causes' in the UK. However, we do see a large increase in mortality from alcohol-related liver diseases in England & Wales, which is not seen in the Netherlands.

Different drivers of these causes may be operating in the two countries:

- Less exposure to COVID-19 during the pandemic may be causing higher mortality in the Netherlands in 2022 due to a lower immunity in the population.
- But conversely, a larger number of COVID cases in England & Wales might cause more lasting frailty due to respiratory, circulatory and other organ damage caused by severe COVID infections (postacute sequelae of SARS-CoV-2 infection (PASC) or long COVID)
- Issues with the provision of healthcare might be more significant in England & Wales, and drive higher mortality from heart diseases and cancers (although this has yet to be observed)
- Behavioural changes during the pandemic might explain the higher rates of liver cirrhosis that England & Wales has seen during and after the pandemic

- Higher deaths reported due to 'ill-defined symptoms' seem to reflect specific features of how cause of death is coded in the Netherlands

Turning to projections, monthly deaths due to COVID-19 continue to fall as the virus approaches its long-term endemic state. This is something we will want to factor explicitly into any projections of the future. Once we have identified the main drivers of excess mortality, we can start to make forecasts for how these may change in future.

To incorporate these into the modelling, we decompose percentage excess from specific causes into age/period terms and add these as offsets to our model structure. For example, in terms of COVID, we use singular-value decomposition to give COVID excess mortality age/period terms for 2022-2023, while the period term is projected by halving each year from 2023. The offset 'explains' a portion of the excess seen in the historic data and 'guides' its run-off in the future. The model is now only responding to the unexplained residual. Multiple adjustments may be needed, but each can be separately informed by different causal drivers and run off over different periods.

In summary: the COVID-19 pandemic represents a shift in the level and trends in mortality rates, which cannot be ignored in the data; developments in modelling are required to quantify the impact of different drivers on post-pandemic mortality and then incorporate these into projections; and these need to bring together people from different disciplines – models without a narrative are insufficient, but a narrative that does not make quantifiable forecasts is not actionable.

- Andrea Staehr (Head of International Longevity Business, Hannover Re) gave a presentation entitled 'Creating awareness for an ignored risk – The Australian journey (or longevity risks in the Australian retirement market)'. The first part was about 'understanding the market'. Australia has the 5$^{th}$ best pension system in the world, according to the Mercer CFA Institute Global Pension Index 2023. The private superannuation funds have AUD3.9trn in assets, there is a 12% mandatory employer contribution, and the state 'age pension' provides a safety net. However, during the retirement phase, there is a lack of diversity and choice: 84% of retirement savings are in account-based pensions; people largely self-insure against longevity risk; and only 3.5% of assets are invested in lifetime income products. Around 2.5mn Australians are due to retire in the next 10 years. There are currently discussions on the regulatory side: the aim is to encourage people to buy annuity products. In the future, it is expected that members will get an

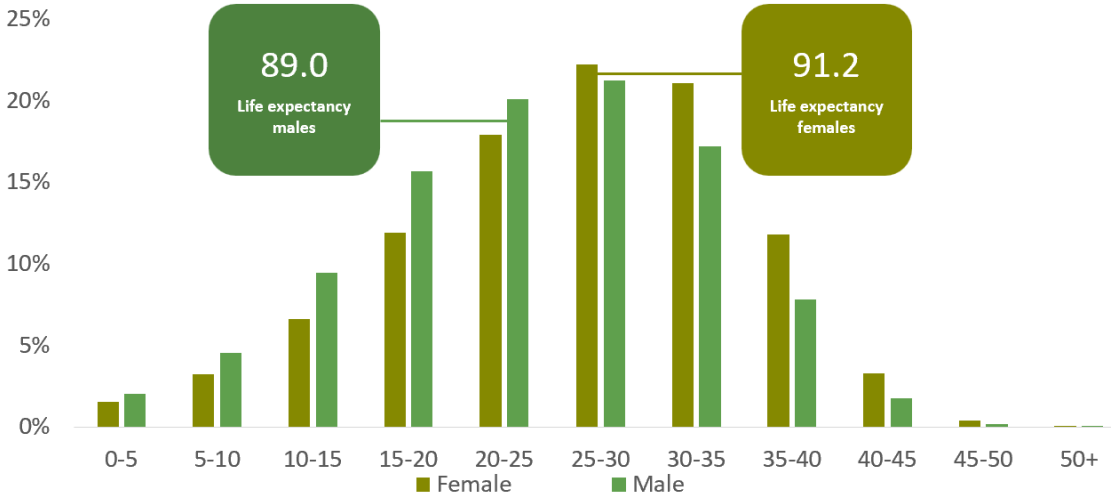
annuity by default. Also, social welfare rules may change to encourage the purchase of annuities.

The second part was about 'creating awareness'. This requires understanding the Australian customer. Australians are used to managing their own investment portfolio, making choices and getting advice. However, Australians are cautious when it comes to spending Super. Despite minimum drawdown rates for account-based pensions, large Super funds remain at death for many Australians.

There is a well-established puzzle in behavioural economics, the annuity puzzle. Although it is financially rational to invest into a lifetime income product, many people abstain from buying one. Among the reasons why are: unattractive locked-in interest rates, loss in liquidity and flexibility, loss of retirement assets upon early death: 'I am not going to live that long!'. Solutions to the puzzle lie in tailored products, customer education, consumption (rather than investment) framing, and marketing as insurance.

Education is vital in creating awareness of: (increasing) life expectancies, lifespan variability, risk of outliving funds; lifetime income as an insurance to secure the standard of living; long-term financial planning in retirement; and suitable lifetime income products. The target audience for this education covers the whole industry: customers, financial advisers, superannuation fund managers, insurers/vendors, and policymakers.

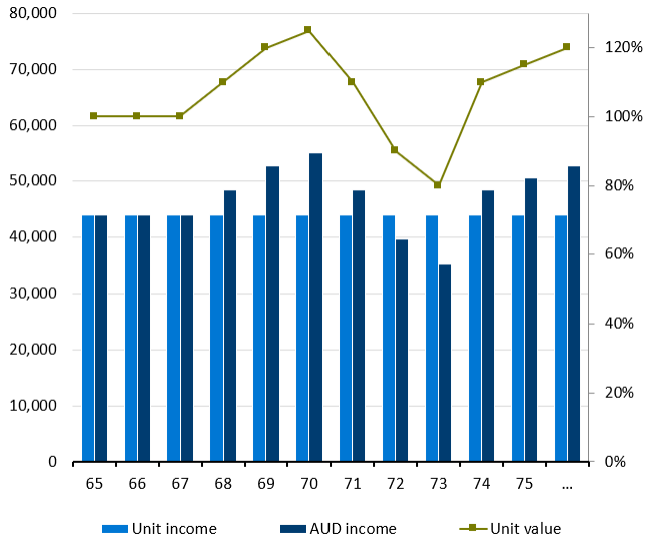
A greater awareness of how long people will live is key to helping Australians plan their retirement. One company has introduced the Lifespan Calculator (www.optimumpensions.com.au/lifespan-calculator). It is also important to understand lifespan variability. The projected distribution of remaining lifespans for healthy pensioners of age 65 is very wide:



The third part was called ‘developing solutions’. Hannover Re is venturing into a new market and supporting vendors and financial advisers with:

- Market insight: combine local market know-how and worldwide longevity expertise.
- Customer education: cooperate with partners to create awareness for longevity risks and potential solutions.
- Product development: support partners in developing products.
- Biometric assumptions: develop appropriate mortality assumptions for pricing and customer education purposes.
- Reinsurance support: provide expertise and capacity to take on biometric risks using suitable reinsurance structures.
- Long-term partnerships: prepare to commit for the longer term – things might take time!

A key innovation is an investment-linked lifetime income product with the following properties: single premium payment, income guaranteed for life, and income amount guaranteed in investment units or as a withdrawal percentage.




There are also flexible investment choice and switching options: flexible income withdrawal, surrender options, and deferment options.

The final part was called ‘achieving success’. The focus in the Australian market is turning towards the retirement phase. Legislation (the Retirement Income Covenant) has been introduced which ensures all Super funds have a strategy for retirement. Funds are aiming to launch products in the near future. New lifetime income products are hitting the market. If successful,

this means that a new longevity market will be developing in Australia. But success will depend on market insight, product fitness, education, and flexibility.

- Plenary Session 4: The Netherlands, pension reforms, and opportunities for buy-out

    - Wichert Hoekert (WTW) gave a presentation entitled 'Views from a consultant'. He began by explaining the Dutch pension reforms: all future accrual will be in DC, the default is to transfer past accrual in pension funds (including benefits in payment) to DC as well, and the accrual pattern is to change by moving to age-independent accrual values. Wichert asked why change a system that seemed to work? The answer is to: better fit current and future labor markets, improve (perceived) generational fairness, improve transparency, increase freedom of choice, and achieve better purchasing power.

      The new contract types:

| | Solidarity arrangement | Flexible arrangement |
|---|---|---|
| Pension promise | (Defined) contribution | Defined contribution |
| Investment policy | Collective asset mix with age-related return allocation *(top down)* | Individual asset mix based on age-related life cycle *(bottom up)* |
| Solidarity buffer | Mandatory | Optional |
| Leverage | Allowed | Not allowed |
| Illiquid assets | Easily accessible | Not easy |
| Type of annuity | Variable annuity | Choice between variable and fixed annuity |

      There will be a solidarity reserve and risk-sharing reserve, whose primary purpose is to restrict or prevent negative benefit adjustments:

| Solidarity arrangement | Flexible arrangement |
|---|---|
| Solidarity reserve<br>• Mandatory<br>• Initial funding out of scheme assets allowed<br>• Maximum 10% of contribution<br>• Maximum 10% of excess return | Risk-sharing reserve<br>• Mandatory only in case of a mandatory plan<br>• Initial funding out of scheme assets allowed<br>• Maximum 10% of contribution / capital at retirement |

| | |
|---|---|
| • Maximum at 15% of total assets<br>• Also, for hedging unexpected inflation<br>• Remains within scheme at individual value transfer | • Maximum at 15% of total assets<br>• Cannot be used to compensate for investment return if members have freedom of choice for risk profile<br>• Also, for hedging unexpected inflation<br>• Remains within scheme at individual value transfer or annuity purchase |

Wichert then discussed the prospects for the pension risk transfer (PRT) market in the Netherlands. In mid-2023, there were 178 pension funds remaining (comprising industry-wide pension funds, company pension funds, professional pension funds and 5 general pension funds) with €1.450bn in assets. The PRT opportunities comprise:

- Company pension funds that close down. Trustees and sponsors are no longer convinced of sustainability and added value, so seek a buy-out. Although an alternative to buy out would be to merge with a general pension fund or an industry-wide pension fund.
- Fixed annuities in case of transfer to a flexible arrangement. This would apply to current retirees and would be ongoing for future retirees.
- Potential partial buy outs. A particular example could be a 'pensioner carve out', although this is not formally part of the legislation. It could however be attractive if pensioners (or groups of pensioners) object to a transfer the new regime.

Wichert then asked what will drive the size of the PRT market? First, funding ratios: higher funding ratios allow pension funds to purchase inflation protection at buy-out. However, current fiscal constraints continue to apply after PRT, but cease to exist after transfer to the new regime: so at very high funding ratios, transfer to the new regime becomes more attractive. Second, public perceptions: how do members look at insurers on the one hand and the new regime on the other? Third, market capacity: can the market absorb transfers within required timeframes?

Next Wichert considered the choice for annuity type for existing retirees. Accrued benefit becomes an individual amount at the transition to a flexible arrangement. Based on the individual amount, the level of the variable annuity is determined (depending on projected returns). The individual amount (excluding any share in collective reserves) can be taken out of the

scheme to purchase a fixed annuity. There are a number of variants of annuities: individual purchase ('each on their own'), collectively outside of the pension fund, collectively within the pension fund, and insured within the pension fund.

In terms of longevity risk, the legislation distinguishes three sources of risk: investment risk, actual mortality, and changes in lifetime expectancy. Pension funds have to determine for each age group to what extent members will be protected against the impact of changes in lifetime expectancy (protection returns), as well as to what extent they pay for these protections (excess returns). The solidarity reserve can be used to absorb the excess returns. However, in scenario analyses, longevity risk is typically neglected. It may be worth investigating how longevity hedging could contribute to the efficiency of the solidarity reserve. Legal constraints for how to assign portfolio returns have to be taken into consideration.

- Marc Meertens (Head of Balance Sheet Management at NN Leven) gave a presentation called 'Views from an insurer' concerning the new PRT opportunities. Company pension funds in the Netherlands will convert existing entitlements to new types of defined contribution arrangements ('invaren'). There is the option to keep the existing DB arrangements for already accumulated reserves. For closed company pension funds and/or company pension funds with relatively aged participants, a more beneficial option is to transfer these defined benefit arrangements to an insurer, via a buy-out.

  What is the rationale for a buy-out? From a company pension fund perspective: securing future pay-outs for its participants, no need for complex transitions, no additional administration issues, and avoiding new legislation requirements etc. From an insurer perspective: acquiring assets under management (AuM) to increase capital generation, improve cost efficiency etc, 'funded' by pension liabilities within the 'sweet-spot' of a pension and life insurer (from an operational and risk management perspective). From a policyholder perspective: obtaining a secured future pension pay-out including (non-discretionary) indexation.

  In terms of capital and risk management, there are challenges for an insurer. The market expects €20-30bn AuM of relative smaller company pension funds to opt for a buy-out, with more pending amongst others depending on funding ratios. But pension liabilities are capital intensive under Solvency II – predominantly driven by longevity risk impacting Solvency Capital Requirement (SCR) (denominator) and Own Funds, through Risk Margin (nominator). There needs to be diligent management of the acquired longevity risk.

The solutions being considered are:

- Longevity risk transfer through full-indemnity based longevity reinsurance. The market has moved away from index-based longevity reinsurance (common in the mid-2010s), given the basis risk and regulatory scrutiny on effective risk transfer under Solvency II. The focus by the Dutch regulator has switched to reinsurance counterparty risk and to the bail-in arrangements of the cedant.
- Asset-intensive reinsurance, which transfers biometrical risks and also (part of) the risks on the asset side. A potential solution is to also mitigate market risk (on the AuM acquired). However, the Dutch regulator is currently sceptical and further regulations/requirements are expected.

- Rohit Mathur (Head of International Reinsurance, Prudential Financial) gave a presentation called 'Views from a re-insurer'. He began by looking at the risk transfer opportunities under the new pension arrangements. The first opportunity was company pension funds that close down leading to potential partial buyouts or to the sale of fixed annuities in case of flexible arrangements. A DB pension plan could transfer its liabilities to a Dutch insurer which would pay the benefits. The insurer could enter into a longevity risk transfer contract with a reinsurer to hedge longevity risk. The insurer would benefit from capital relief and the risk management skills and human resource capacity of the reinsurer.

  The second opportunity was risk transfer opportunities in solidarity arrangements. Large pension funds may choose solidarity arrangements. A solidarity buffer will be used to manage volatility. Can longevity hedging contribute to the efficiency of the solidarity reserve? If so, a DB pension plan could transfer its liabilities to a captive insurer which would pay the benefits. The captive would enter into a longevity risk transfer contract with a reinsurer to hedge longevity risk. The captive would benefit from a buffer and the risk management skills of the reinsurer.

  Rohit concluded by pointing out that the future path of longevity and mortality are unpredictable. Globally, mortality-oriented insurance business has exceeded longevity-oriented insurance businesses. Life reinsurers can balance these exposures. Pension risk transfer has been the most significant driver of growth in longevity-oriented business since 2012.

- Eilidh Brown (Willkie) gave a presentation called 'Views from a legal/regulatory perspective'. Once a PRT market is established, insurers look to reinsurers to manage longevity risk and cashflows. If the expected volume of liabilities is transferred, insurers will need the capacity of the reinsurance markets. Previous focus in the Netherlands was on index-linked longevity derivatives. Indemnity-based reinsurance offers clearer effective

risk transfer and therefore a better opportunity to reduce capital requirements associated with longevity risk. Longevity reinsurance market can use 'technology' from other more developed markets, such as the UK. Some transactional issues may be specific to the Dutch market, however, so different approaches may be required.

Eilidh then discussed some transactional issues:

- DNB approval. As a nascent market, participants can expect more involvement from the DNB (the Dutch National Bank, the financial regulator) as transactions and structures develop. Counterparty credit risk is likely to be of concern to the DNB.
- Collateral. The following issues will be material: structure of collateral arrangements (e.g., title transfer, security and control agreement), location of the collateral, triggers for accessing the collateral, and rebalancing
- Accommodating a bail-in. While not (yet) a feature of UK transactions, the Dutch Recovery and Resolution Act (applicable since 2019) allows for bail-in of insurer. An insurer's pension obligations might be reduced – how will the reinsurer respond?
- Data protection. The EU has strict rules about personal data leaving the jurisdiction of the EU.

Finally, Eilidh then discussed funded reinsurance. Funded (or asset-intensive) reinsurance market is growing in jurisdictions such as the UK. It allows insurers to pass on some of the asset risk as well as the longevity risk to reinsurers. There is potential for growth in the Dutch market. However, the current view is that the DNB is unlikely to approve of funded reinsurance at this stage. The focus of concerns of regulators including the PRA in the UK and the NAIC in the US include: counterparty credit risk, the removal of assets out of the regulator's jurisdiction, the ability to adequately assess asset risk, particularly in respect of illiquid assets, and the ability to recapture assets in a timely manner where required.

The academic papers that were selected for this Virtual Special Issue went through a refereeing process subject to the usual high standards of *Insurance: Mathematics & Economics*. They cover the following themes: longevity indices, longevity risk transfers, reverse mortgages, pensions, annuities, mortality models and mortality forecasting, Covid-19 mortality, climate-related mortality, and the link between subjective well-being and mortality. The 17 papers selected are briefly discussed below.

In 'Avoiding a longevity catastrophe: Harnessing longevity indices to mitigate individual, institutional and systemic longevity risks', Guy Coughlan considers the financial implications of an extreme increase in life expectancy for: (i) individuals with defined

contribution pension plans and other forms of retirement savings; (ii) institutions such as defined benefit pension plans, insurance companies and reinsurers; and (iii) the financial system and economy as a whole. An extreme longevity scenario, as the IMF first acknowledged in 2006, is a long-term systemic risk that could impair the operation of the financial system with severe ramifications for the global economy. It also poses a significant risk to individuals who might live beyond the time that their retirement savings can support them. This paper explores one under-utilised way to mitigate these risks, viz., longevity index hedges, which can transfer longevity risk simply, rapidly and transparently away from where it is concentrated to a much broader set of organisations with appropriate levels of risk capital. For the market in these index hedges to grow requires a shared understanding of the hedges and their risk reduction potential by the insurance industry and regulators.

In 'Contract structure and risk aversion in longevity risk transfers', David Landriault, Bin Li, Hong Li and Yuanyuan Zhang develop an economic framework for optimal longevity risk transfer between a buyer and a seller with different risk aversions. The authors compare static (long-dated, pre-committed) and dynamic (short-dated, rolled) longevity swaps in a Stackelberg game. They find that static contracts are preferred when the buyer is more risk averse, while dynamic contracts are preferred when the seller is more risk averse. For the capital-market setting, they extend the benchmark by introducing seller-side ambiguity about the mortality distribution and robust max-min valuation. Even moderate ambiguity can eliminate the market for static swaps, while dynamic designs remain viable. The authors then extend the analysis to index-based swaps with basis risk: relative to indemnity swaps, optimal loadings are lower and gains are smaller for both parties, though the static–dynamic preference pattern is unchanged.

In 'Reverse mortgages with long-term care cost coverage: The role of health state granularity in valuing prepayment options', Tian-Shyr Dai, Liang-Chih Liu, Shang-Hung Tsao, and Sharon S. Yang point out that the growing elderly population has intensified interest in financial products such as reverse mortgages (RM) with long-term care (LTC) cost coverage, which provide funding solutions for senior homeowners facing income shortfalls and rising care costs. Their study advances existing research on reverse mortgage contracts with long-term care cost coverage (RM LTC) by systematically examining how the granularity of health state information influences contract valuation, particularly in the presence of prepayment options and market risks. They develop a numerical framework to determine the fair annuity rate of RM LTC contracts. The framework jointly captures stochastic house prices, interest rates, and multiple-health-state transition matrices calibrated with real-world disability data. Their results show that finer health state granularity improves the precision of prepayment decisions, increasing the value and therefore the cost of embedded options while lowering fair annuities. Conversely, relying on less detailed health information leads to an underestimation of

option value and results in higher annuities offered to homeowners. By clarifying these mechanisms, the study underscores the pivotal role of health state granularity in valuing RM LTC contracts and provides insights into the design of home-equity-based financing for long-term care.

In 'Life care reverse mortgages: Monitoring the net cashflows of a new hybrid insurance product', Giovanna Apicella, Emilia Di Lorenzo, Giulia Magni and Marilena Sibillo argue that combining retirement income and long-term disability protection is a well established concept in the literature. They present a new connection between the lifetime annuity provided by a reverse mortgage and long-term care (LTC) insurance, jointly managed in a unique bundled product. Indeed, they define the RM (considered as a source of lifetime income) and LTC as two different regimes of a jointly managed insurance product, which they call the 'Life care reverse mortgage' (LCRM). From an actuarial perspective, the authors design the underlying structure of the LCRM and the inherent framework for the ex-ante estimation of a time-dependent profit/loss function, that provides a measure of the expected annual net cashflows for a life insurer holding a portfolio of LCRMs. They then perform a numerical application to illustrate the regime-switching mechanism on which the proposed LCRM insurance contracts are based and to quantify over time the lender's return for a pool of LCRM contracts through the designed time-dependent profit/loss function. Furthermore, they analyse the sensitivity of the portfolio profit/loss function to two sources of uncertainty: health patterns over time and house price dynamics.

In 'The Big Thaw: Unfreeze defined benefit pension with cash balance plans', Yijia Lin and Tianxiang Shi point out that the recent resurgence of defined benefit (DB) pensions through cash balance (CB) plans has sparked discussions and captured the attention of employers, unions, and benefits experts. However, there remains limited understanding of how unfreezing DB pensions impacts a firm. To address this gap, the authors explore the cost and benefit tradeoffs associated with pension unfreezing using a model calibrated to market data within a stochastic framework. Their analysis reveals that the extent to which restarting DB pensions affects a firm's total pension cost depends on factors such as pension surplus magnitude, employee salaries, firm financial stability, and Pension Benefit Guaranty Corporation (PBGC) premiums. In particular, with a high funding surplus and elevated employee salaries, unfreezing a CB plan can yield greater cost efficiency for companies than pension risk transfer, especially in a high interest rate environment. The authors' findings provide valuable insights for pension sponsors contemplating the reopening of DB pensions through CB plans, which could potentially counteract the current trends in pension de-risking.

In 'Rethinking the annuity puzzle: The role of loss aversion and money-back guarantees', Sebastian Hallstein, Daniel Liebler and Raimond Maurer argue that consumption and saving models typically suggest accumulation in life-only annuities that is at odds with

actual investments. Milevsky and Salisbury (2022)[1621] add another dimension to this annuity puzzle by documenting a shift from life-only annuities to those offering money-back guarantees to the heirs of the annuitant. The authors provide further evidence for a balanced coexistence of both annuity types; however, standard utility frameworks that rely solely on consumption and bequest utility fail to reproduce this relationship. To overcome the dominance of life-only annuities, they incorporate loss aversion into individual preferences. Specifically, they assume aversion to dying before the total payouts exceed the premiums paid, creating a natural obstacle to life-only annuities. Using realistically calibrated life cycle models with access to liquid savings and both life-only and refundable annuities, they show that loss aversion can flexibly control the demand for annuities, thereby enabling a balanced relationship between the annuity types. While the authors' findings shed further light on behavioral drivers behind the annuity puzzle, their utility framework does not simultaneously establish the empirical relationship across annuity types as well as the overall demand for annuities.

In 'Robust parameter estimation for the Lee-Carter family: A probabilistic principal component approach', Yiping Guo and Johnny Siu-Hang Li point out that although the impact of outliers on stochastic mortality modelling has been examined, previous studies on this topic focus on how outliers in the estimated time varying indexes may be detected and/or modelled, with little attention being paid to the adverse effects of outliers on estimation robustness, particularly that pertaining to age-specific parameters. In this paper, the authors propose a robust estimation method for the Lee-Carter model, through a reformulation of the model into a probabilistic principal component analysis with multivariate $t$ distributions and an efficient expectation maximization algorithm for implementation. The proposed method yields significantly more robust parameter estimates, while preserving the fundamental interpretation for the bilinear term in the model as the first principal component and the flexibility of pairing the estimated time-varying parameters with any appropriate time-series process. Thay also extend the proposed method for use with multi-population generalizations of the Lee-Carter model, allowing for a wider range of applications such as quantification of population basis risk in index-based longevity hedges. Using a combination of real and pseudo datasets, they demonstrate that the superiority of the proposed method relative to conventional estimation approaches such as singular value decomposition and maximum likelihood.

In 'An empirical study of small populations based on Taiwan's data', Hsin-Chung Wang and Jack C. Yue argue that the estimation of mortality and disease incidence rates for small populations poses significant challenges for insurers in meeting regulatory compliance requirements, such as those imposed by the European prudential framework Solvency II.

[1621] Milevsky, M. A. and T. S. Salisbury (2022) 'Refundable income annuities: Feasibility of money-back guarantees', *Insurance: Mathematics &Economics,* 105: 175–193.

These difficulties primarily arise from data scarcity and the substantial volatility inherent in estimates derived from limited observations. To alleviate these issues, several methodologies have been proposed that effectively enlarge the underlying data set – for instance, through multi-population mortality models or the incorporation of reference populations – to reduce the stochastic variation in small-sample estimates. Such approaches, however, rest critically on the assumption that the reference population exhibits comparable demographic and epidemiological characteristics to those of the target population. A frequently adopted strategy involves pooling data from geographically adjacent districts; nevertheless, neighboring areas often differ markedly in their socioeconomic and demographic compositions, which may induce pronounced heterogeneity in age-specific mortality and incidence patterns. In this study, the authors propose a data-driven framework for identifying suitable reference populations to enhance the accuracy of mortality estimation in small populations. Specifically, cluster analysis is employed to group small populations together with their neighboring districts, thereby constructing reference populations using techniques grounded in the heterogeneity measures proposed by Lee (2003).[1622] The study areas are partitioned into clusters exhibiting intra-group homogeneity and substantial inter-group heterogeneity in mortality rates. The proposed methodology is empirically validated using mortality data at the county and township levels in Taiwan. Based on the constructed reference populations, life tables are established, and life expectancy estimates for small populations are subsequently derived.

In 'Quantile-based interpretable neural network models: Mortality forecasting and actuarial simulations', Yang Qiao, Jinggong Zhang, Wenjun Zhu and Chou-Wen Wang introduce a class of quantile-based, interpretable neural network (NN) models for mortality prediction: the Lee-Carter neural network (LCNN) model, the Renshaw-Haberman neural network (RHNN) model, and the simple neural network (simpleNN) model that balances simplicity with predictive performance. These models preserve the linear interpretability of classic stochastic mortality models while harnessing the flexibility of NNs to capture complex nonlinear patterns in mortality data, thereby achieving enhanced predictive performance. Leveraging a composite loss function that integrates pinball, median anchoring, and quantile-crossing penalty terms, the authors estimate mortality quantiles and develop an efficient simulation scheme based on interpolation. This framework provides distributional insights essential for pricing, reserving and risk management. Extensive empirical analyses across multiple populations demonstrate that the proposed models consistently outperform traditional approaches in predictive accuracy. Their practical utility is illustrated through an application to longevity swap pricing.

In 'The future of mortality: Mortality forecasting by extrapolation of deaths curve evolution patterns', Matthias Börger, Martin Genz, and Jochen Ruß point out that a variety of mortality models can be used to project future mortality. However, the parameters of

[1622] Lee, W.C. (2003) 'A partial SMR approach to smoothing age-specific rates', *Annals of Epidemiology*, 13(2): 89-99.

most of these models lack a clear demographic interpretation. Hence, the resulting projections may be demographically implausible in the sense that trends in key demographic statistics are not extrapolated in a reasonable way. When demographers make predictions on future mortality, they typically focus on one or few relevant demographic statistics related to certain aspects of the mortality evolution. However, they do not derive comprehensive mortality forecasts as required for actuarial purposes. This article aims to close the gap between these forecasting approaches. To this end, the authors establish a new deterministic mortality model which can be used for best estimate and scenario forecasts. They model the deaths curve, i.e. the age-at-death distribution, and derive forecasts based on the extrapolation of statistics that have a clear demographic interpretation. The four key statistics of the model are those from the classification framework of Börger et al. (2018).[1623] The design of the model makes sure that forecasts for the immediate future of the deaths curve are consistent with the most recent trends of all demographically relevant statistics. Moreover, expert opinions with respect to the future trends of certain demographically interpretable statistics can easily be incorporated – in particularly for the farther future where a pure extrapolation of historic trends might lead to implausible results. Finally, the authors present a possible implementation of the model and provide case studies that illustrate how the model can be applied.

In 'Scanning the horizon: Integrating expert knowledge into the calibration of stochastic mortality models', Richard G.A. Faragher, Arne Freimann and Jochen Ruß argue that expert knowledge from many different disciplines has the potential to inform on developments that could significantly increase or decrease human life expectancy. However, such knowledge is typically not considered in longevity risk management, since stochastic mortality models are generally only calibrated to historical mortality patterns, i.e., are fully data-driven. Following an interdisciplinary approach, the authors develop a methodology for how expert knowledge on the (uncertainty of the) future of human life expectancy can be integrated into the calibration of stochastic mortality models. They argue that this approach is particularly relevant if there are 'low probability / high impact' scenarios on the horizon, that are considered plausible by experts in their respective field but are 'virtually impossible' in models calibrated to historical data. Based on current research on treatments that might be effective in slowing down ageing, the authors motivate and propose an exemplary plausible scenario for the future development of human life expectancy. They assign a potential impact on life expectancy as well as a plausible probability of occurrence to the scenario and present a method for calibrating stochastic mortality models so that the resulting projections are in line with these parameters. In a case study, they analyse and compare the longevity risk in an exemplary annuity portfolio

[1623] Börger, M., Genz, M., and Ruß, J. (2018) 'Extension, compression, and beyond – A unique classification system for mortality evolution patterns', *Demography*, 55(4): 1343-1361.

and show that this so-called ‘driver-driven’ calibration can lead to a structurally different assessment of longevity risk than the traditional ‘data-driven’ approach, especially with regard to tail risks.

In ‘Prolonging life by vitagions: Modelling of mortality improvement shocks’, Maria Carannante, Valeria D’Amato and Cinzia Di Palo argue that changes in life expectancy are commonly used to track shifts in mortality dynamics, yet they are hard to interpret, especially during so-called mortality shocks that arrive suddenly, are temporary, and run counter to the long-run trend. Purely extrapolative models cannot capture such changes. Therefore, The authors propose a forward-looking extension of the Lee-Carter framework, which integrates mortality improvements due to ‘vitagions’. Vitagions are individual sources of mortality improvement, and projects how these might unfold in the future. To model mortality increases related to medical innovation, the authors consider extending the Lee-Carter model to capture heterogeneity in morality (i.e., a frailty-based model) and include a jump diffusion process estimated as a function of the relationship between medical progress and mortality trends to improve mortality projections.

In ‘Beyond annual data: Mortality forecasting with mixed-frequency data’, Runze Li, Rui Zhou and David Pitt argue that existing mortality models typically rely on annual data, with forecasts for a given year based on information available up to the end of the previous year. However, technological advances have enabled the collection and production of weekly and monthly death data, offering new opportunities to improve forecasting. Using only annual data overlooks the full range of available information. In this paper, the authors propose mixed frequency sampling (MIDAS) models to integrate monthly death counts (high frequency) with annual mortality rates (low frequency), enabling improved short-term prediction of annual mortality. Extending economic applications of MIDAS, which typically predict single variables such as GDP growth, their MIDAS framework accounts for age dependence unique to age-specific mortality modeling. The authors also evaluate different weighting functions, a core element in MIDAS that determines the relative importance of high-frequency data at different lags, and identify suitable weighting functions for mortality forecasting. Using U.S. mortality data, they demonstrate that their approach significantly improves prediction accuracy compared to models relying solely on annual data for short-term forecasting. These findings highlight the potential of MIDAS models as a useful tool for accurate and timely mortality forecasts.

In ‘ADM's APPLE: The Accelerated Deaths Model with an application to the Covid-19 pandemic’, Andrew J.G. Cairns and David Blake introduce the Accelerated Deaths Model (ADM) which builds on the hypothesis that, within a given age cohort, those who are less healthy are more likely to die if infected with Covid-19 than healthier people, leaving a pool of on-average healthier survivors. They use the term ‘detrimental selection’ which has

two complementary aspects: the years of life lost by those who experienced an accelerated death; and the higher average life expectancy of survivors which we call their 'adjusted post-pandemic life expectancy' (ADM's APPLE). Their model represents a novel synthesis of recent advances in our understanding of mortality heterogeneity and the development of the Proportionality Hypothesis – both of which have improved our understanding of the Covid-19 pandemic. In particular, the authors identify an important positive relationship between mortality heterogeneity and accelerated deaths. They find, in the case of the Covid-19 pandemic in England, that the years of life lost by those who experienced an accelerated death, while significantly lower than pre-Covid life expectancy, was greater than reported in the media at the time. They also find that the increase in the mean life expectancy of survivors was very small. As a result, the impact on annuity providers (e.g., in terms of potentially higher annuity prices), pension schemes and life insurers was also very small. In contrast, the authors find that the impact on life expectancy of a general change in future mortality assumptions post-pandemic (i.e., the base mortality table and improvement rate) would be much greater. The ADM has potentially wide application, e.g., to other types of contagion and to climate-related deaths, where we would expect there to be a positive correlation between deaths and all-cause mortality (consistent with the Proportionality Hypothesis), but where the degree of detrimental selection might be different.

In 'On measuring Covid-19 excess mortality: Insights and challenges', Ayse Arik, Allen Klein, and Han Li examine all-cause excess mortality due to the Covid-19 pandemic across 16 countries by age and sex. Utilising the Short-Term Fluctuations data series from the Human Mortality Database, they analyse various measures of excess mortality on a weekly and yearly basis from 2020 through the end of 2023. They explore the strengths and limitations of different approaches to offer a comprehensive understanding of the pandemic's impact on diverse nations. Specifically, they evaluate two methodologies employed by the UK's Office for National Statistics, considering observed death counts both with and without adjusting for population sizes. They also apply a method based on annual mortality improvements and, as a final approach, implement a statistical model to weekly death counts. Each method defines excess mortality differently, allowing for comparison across alternative perspectives. Their analysis demonstrates largely consistent outcomes across different measures during the first two years of the pandemic, with significant variations in the last two years. These findings contribute to a nuanced understanding of various measures by highlighting their strengths and limitations.

In 'The climate lifespan link: Investigating the influence of temperature change on human mortality', Yijia Lin, Yanxin Liu and Ruilin Tian extend the widely adopted Lee and Carter

(1992) mortality model[1624] by incorporating temperature-related covariates to quantify the impact of climate risk on mortality. Their analysis reveals variation in mortality sensitivity to temperature across different ages. Based on U.S. data, they find that the elderly population is particularly vulnerable to the impacts of climate change. Specifically, seniors aged 65-70 are most susceptible to extreme cold, while those aged 65-75 are most vulnerable to hot weather. Additionally, the effects of cold and hot weather on mortality differ significantly across various contiguous U.S. divisions. Their proposed Temperature Lee-Carter (TLC) model projects that, under high-emissions scenarios such as SSP3-7.0 and SSP5-8.5, global warming could increase U.S. mortality rates among individuals aged 65 and above by 13.05% to 27.22% by 2099, with younger seniors (65-75) experiencing up to a 42.57% rise—posing substantial challenges for public health systems and the financial sustainability of life insurance markets. Their results suggest that the effect of global warming on mortality counteracts the current population aging trends, which have important implications for mortality risk management.

Finally, in 'Mortality risks, survival pessimism, and subjective well-being: Evidence from the Health and Retirement Study', Lisa Posey, Sharon Tennyson and Nan Zhu point out that the positive relationship between an individual's subjective well-being (SWB) and their future survival prospects has been well documented. Using data from the Health and Retirement Study (HRS), they present empirical evidence of how this relationship operates through various channels. They use a two-stage approach where objective survival probability estimates derived from a first-stage Cox model are used to construct the survival bias employed as the dependent variable in the second stage, with SWB and other demographic and health-related variables being covariates in both stages. Their findings reveal that even after controlling for objective health-related factors and potential private information on health and mortality, individuals' SWB remains as a significant factor to their objective mortality. Moreover, respondents' SWB also affects the bias in the survival estimation—measured as the disparity between their subjective and objective survival probabilities. In particular, a higher SWB is correlated with a reduction in survival pessimism. The authors provide new evidence that bias in survival estimates can distort consumption and saving decisions, and provide estimates of its impact on welfare across different levels of SWB.

*Longevity 20* took place in Singapore on 8–9 September 2025; the *Journal of Risk & Insurance* will publish a special issue of the best papers presented at the conference. *Longevity 21* took place in Rome on 8-9 September 2026. *Longevity 22* is planned for Toronto on 7-8 September 2026.

[1624] Lee, R. and L. Carter (1992) 'Modeling and forecasting U. S. mortality', *Journal of the American Statistical Association*, 87(419), 659–671.

## References


Acemoglu, D., and Johnson, S. (2007) 'Disease and Development: The Effect of Life Expectancy on Economic Growth', *Journal of Political Economy,* 115(6): 925-985.

Acemoglu, D., and Restrepo, P. (2020) 'Robots and Jobs: Evidence from U.S. Labor Markets', *Journal of Political Economy*, 128(6): 2188–2244.

Acemoglu, D., and Restrepo, P. (2022) 'Demographics and Automation', *Review of Economic Studies*, 89(1): 1-44.

Agarwal, A., Ewald, C. O., and Wang, Y. (2023) 'Hedging Longevity Risk in Defined Contribution Pension Schemes', *Computational Management Science*, 20(1): 1-34.

Ai, J., Brockett, P.L., Golden, L.L, and Zhu, W. (2017) 'Health State Transitions and Longevity Effects on Retirees' Optimal Annuitization', *Journal of Risk and Insurance*, 84(S1): 319-343.

Ai, J., Brockett, P. L., and Jacobson, A. F. (2015) 'A New Defined Benefit Pension Risk Measurement Methodology', *Insurance: Mathematics and Economics*, 63: 40-51.

Aksoy, Y., Basso, H. S., Smith, R. P., and Grasl, T. (2019) 'Demographic Structure and Macroeconomic Trends', *American Economic Journal: Macroeconomics,* 11(1): 193-222.

Alai, D. H., Arnold, S., Bajekal, M., and Villegas, A. M. (2018) 'Mind the Gap: A Study of Cause-Specific Mortality by Socioeconomic Circumstances', *North American Actuarial Journal*, 22(2): 161-181.

Alai, D. H., Arnold, S., and Sherris, M. (2014a) 'Modelling Cause-of-Death Mortality and the Impact of Cause-Elimination', *Annals of Actuarial Science*, 9(01): 167–186.

Alai, D. H., Chen, H., Cho, D., Hanewald, K., and Michael Sherris, M. (2014b) 'Developing Equity Release Markets: Risk Analysis for Reverse Mortgages and Home Reversions', *North American Actuarial Journal*, 18(1): 217-241.

Alai, D. H., and Sherris, M. (2014) 'Rethinking Age-Period-Cohort Mortality Trend Models', *Scandinavian Actuarial Journal*, 2014(3): 208-227.

Albrecher, H., Bladt, M., and Yslas, J. (2022) 'Mortality Modeling and Regression with Matrix Distributions', *Insurance: Mathematics and Economics*, 107(C): 68-87.

Alho, J. M. (1990) 'Stochastic Methods in Population Forecasting', *International Journal of Forecasting*, 6(4): 521–530.

Alho, J. M. (1991) 'Effect of Aggregation on the Estimation of Trend in Mortality', *Mathematical Population Studies*, 3(1): 53–67, 1991.

Aleksic, M.-C., and M. Börger (2012) 'Coherent Projections of Age, Period, and Cohort Dependent Mortality Improvements', Discussion Paper, University of Ulm.

Aliverti, E., Mazzuco, S., and Scarpa, B. (2022) 'Dynamic Modelling of Mortality Via Mixtures of Skewed Distribution Functions', *Journal of the Royal Statistical Society Series A (Statistics in Society)*, 185(3): 1030–1048.

Alonso-García, J. (2023) 'Mortality: from Lee–Carter to AI', *Annals of Actuarial Science*, 17(1): 212-214.

Álvarez, J.-A., Kallestrup-Lamb, M., and Kjærgaard, S. (2021) 'Linking Retirement Age to Life Expectancy Does Not Lessen the Demographic Implications of Unequal Lifespans'*, Insurance: Mathematics and Economics*, 99(C): 363-375.

Ando. A., and Modigliani, F. (1963) 'The "Life Cycle" Hypothesis of Saving: Aggregate Implications and Tests', *American Economic Review*, 53(1, Part 1): 55-84.

Antolin, P. and Blommestein, H. (2007) 'Governments and the Market for Longevity-Indexed Bonds', Organization for Economic Cooperation and Development Working Papers on Insurance and Private Pensions, No. 4, OECD Publishing, Paris.

Antonio, K., Bardoutsos, A. And Ouburg, W. (2015) 'A Bayesian Poisson Log-Bilinear Model for Mortality Projections with Multiple Populations', *European Actuarial Journal,* 5(2): 245–281.

Antonio, K., Devriendt, S., de Boer, W., de Vries, R., De Waegenaere, A., Kan, H-K., Kromme, E., Ouburg, W., Schulteis, T., Slagter, E., van der Winden, M., van Iersel, C., and Vellekoop, M. (2017) 'Producing the Dutch and Belgian Mortality Projections: A Stochastic Multi-Population Standard', *European Actuarial Journal*, 7(2): 297–336.

Apicella, G., Dacorogna, M., Di Lorenzo, E., and Sibillo, M. (2019) 'Improving the Forecast of Longevity by Combining Models', *North American Actuarial Journal*, 23(2): 298-319.

Apicella, G., Di Lorenzo, E., Magni, M., and Sibillo, M. (2025) 'Life Care Reverse Mortgages: Monitoring the Net Cashflows of a New Hybrid Insurance Product', *Insurance: Mathematics and Economics*; DOI: 10.1016/j.insmatheco.2025.103170

Apicella, G., La Rocca, M., Perna, C., and Sibillo, M. (2024) 'Neural Network Lee–Carter Model and the Actuarial Relevance of Longevity Risk Assessment', Scandinavian Actuarial Journal; DOI: 10.1080/03461238.2024.2443833

Aprea, I. L., Perla, F., Petrella, R. C., Pietroluongo, M., and Scognamiglio, S. (2026) 'The Role of Climate Risk in Shaping Longevity Dynamics: Extending Stochastic Mortality Models', *Socio-Economic Planning Sciences*, 103, 102353

Aragona, M., Günther, S. and Hieber, P. (2025) 'Efficiently Computing Annuity Conversion Factors via Feed-forward Neural Networks', *Annals of Actuarial Science*; DOI: 10.1017/S174849952500003X

Aragona, M., Regis, L., and Vigna, E. (2025) 'A Redistributive GSA Scheme to Cope with Socio-economic Mortality Differentials', *Astin Bulletin*; DOI: 10.1017/asb.2025.16

Arik, A., Klein, A., and Li, H. (2025) 'On Measuring COVID-19 Excess Mortality: Insights and Challenges', *Insurance Mathematics and Economics*; DOI: 10.1016/j.insmatheco.2025.103199

Arık, A., Uğur, Ö., and Kleinow, T. (2023), 'The Impact of Simultaneous Shocks to Financial Markets and Mortality on Pension Buy-Out Prices', *ASTIN Bulletin*, 53(2): 392-417.

Armstrong, J., and Dalby, J. L. (2025) 'Optimal Mutual Insurance against Systematic Longevity Risk, *Scandinavian Actuarial Journal*; DOI: 0.1080/03461238.2025.2546902

Arnold, S., and Glushko, V. (2021) 'Cause-Specific Mortality Rates: Common Trends and Differences', *Insurance: Mathematics and Economics*, 99(C): 294-308.

Arnold, S., and Sherris, M. (2013) **'**Forecasting Mortality Trends Allowing for Cause-of-Death Mortality Dependence', *North American Actuarial Journal,* 17:273–82.

Arnold, S., and Sherris, M. (2015) 'Modelling Cause-of-Death Mortality: What do We Know on Their Dependence?', *North American Actuarial Journal*, 19(2): 116-128.

Arnold, S., and Sherris, M. (2016) 'International Cause-Specific Mortality Rates: New Insights from a Cointegration Analysis', *ASTIN Bulletin*, 46 (1): 9-38.

Aro, H. (2014) ‘Systematic and Non-Systematic Mortality Risk in Pension Portfolios’, *North American Actuarial Journal*, 18(1): 59-67.

Aro, H., and Pennanen, T. (2017) ‘Liability-Driven Investment in Longevity Risk Management. In *International Series in Operations Research and Management Science*, 245: 121–136, New York: Springer.

Arriaga, E. E. (1984) ‘Measuring and Explaining the Change in Life Expectancies’, Demography, 21(1):83–96.

Ashwin, J., and Scott, A. (2025) ‘A Bayesian Model of Later Life Mortality Trends and Implications for Longevity’, Journal of the Royal Statistical Society Series A (Statistics in Society); 189(2):834-850.

Atance, D., and Debón, A. (2025) ‘CvmortalityMult: Cross-Validation for Multi-Population Mortality Models’, *The R Journal*, 17/2; DOI: 10.32614/RJ-2025-018
David Atance del OlmoDavid Atance del OlmoA. DebónA. Debón

Atance, D., Debón, A., and Navarro, E. (2020) ‘A Comparison of Forecasting Mortality Models using Resampling Methods’, *Mathematics*, 8(9): 1550.

Atance, D., Haberman, S., and Millossovich, P. (2025) ‘The Dynamic of Mortality Explained with a Reduced Number of Key Ages’, *Scandinavian Actuarial Journal*; DOI: 10.1080/03461238.2025.2596036

Atance, D., Lledó, J., and Navarro, E. (2024a) ‘Modelling and Forecasting Mortality Rates for a Life Insurance Portfolio’, *Risk Management*, 27(1):3.

Atance, D., and Navarro, E. (2024b) ‘A Simplified Model for Measuring Longevity Risk for Life Insurance Products’, *Financial Innovation*, 10(1): 1-30.

Attia, P. (2023) *Outlive: The Science & Art of Longevity*, London, Vermilion.

Auclert, A., Malmberg, H., Martenet, F., and Rognlie, M. (2021) ‘Demographics, Wealth, and Global Imbalances in the Twenty-First Century’, NBER Working Paper 29161, revised 2024; https://www.nber.org/system/files/working_papers/w29161/w29161.pdf

Awad, Y., Shaul, Bar-Lev, S. K., and Makov, U. (2022) ‘A New Class of Counting Distributions Embedded in the Lee–Carter Model for Mortality Projections: A Bayesian Approach’, *Risks*, 10: 111.

Ayuso, M., Bravo, J. M., Holzmann, R., and Palmer, E. (2021) ‘Automatic Indexation of the Pension Age to Life Expectancy: When Policy Design Matters’, *Risks*, 9(5), 96.

Bacinello, A. R., Millossovich, P., and Viviano, F. (2024) ‘An Iterative Least-Squares Monte Carlo Approach for the Simulation of Cohort Based Biometric Indices’, *European Actuarial Journal*, DOI: 10.1007/s13385-024-00393-5

Backus, D., Cooley, T., and Henriksen, E. (2014) ‘Demography and Low-frequency Capital Flows’, *Journal of International Economics,* 92(Supp. 1): 94-102.

Bahl, R. K., and Sabanis, S. (2021) ‘Model-Independent Price Bounds for Catastrophic Mortality Bonds’, *Insurance: Mathematics and Economics*, 96(C), 276-291.

Bakar, Ö., and Büyükyazıc, M. (2022) ‘Stochastic Analysis of Longevity Risk in Dependent Multiple Life Annuities’, *Sigma J Eng Nat Sci*, 40(2), 235-242.

Balasooriya, U., Li, J. S.-H., and Li, J. (2020) ‘The Impact of Model Uncertainty on Index-Based Longevity Hedging and Measurement of Longevity Basis Risk’, *Risks*, 8(3), 80.

Baldi, G. L., Nigri, A., and Shang, H. L. (2025) ‘Age-Period Modeling of Mortality Gaps: The Cases of Cancer and Circulatory Diseases’, *Journal of Official Statistics*; DOI: 10.1177/0282423X251350772

Balland, F., Boumezoued, A., Devineau, L., Habart, M., and Popa, T. (2020) 'Mortality Data Reliability in an Internal Model', *Annals of Actuarial Science*, 14(2): 420–444.

Balter, A. G., Bjerre, D. S., and Kallestrup-Lamb, M. (2023) 'The Effect of Marital Status on Life Expectancy: Is Cohabitation as Protective as Marriage?', *Journal of Demographic Economics*, 89(3):373-394.

Balter, A. G., Kallestrup-Lamb, M., and Rangvid, J. (2020) 'Variability in Pension Products: A Comparison Study between the Netherlands and Denmark', *Annals of Actuarial Science*, 14(2): 338–357.

Balter, A. G., Kallestrup-Lamb, M., and Rangvid, J. (2021) 'Macro Longevity Risk and the Choice between Annuity Products: Evidence from Denmark', *Insurance: Mathematics and Economics*, 99(C): 355-362.

Barbarin, J. (2008) 'Heath–Jarrow–Morton Modelling of Longevity Bonds and the Risk Minimization of Life Insurance Portfolios', *Insurance: Mathematics and Economics,* 43: 41-55.

Barigou, K., Goffard, P.-O., Loisel, S., and Salhi, Y. (2023) 'Bayesian Model Averaging for Mortality Forecasting using Leave-Future-Out Validation', *International Journal of Forecasting,* 39(2): 674-690.

Barigou, K., Loisel, S., and Salhi, Y. (2021) 'Parsimonious Predictive Mortality Modeling by Regularization and Cross-Validation with and without Covid-Type Effect', *Risks*, 9(1), 5.

Barrieu, P., Bensusan, H., El Karoui, N., Hillairet, C., Loisel, S., Ravanelli, C., and Salhi, Y. (2012) 'Understanding, Modeling and Managing Longevity Risk: Key Issues and Main Challenges', *Scandinavian Actuarial Journal*, 3: 203–231.

Barrieu, P. M., and A.M. Veraart, L. (2016) 'Pricing q-Forward Contracts: An Evaluation of Estimation Window and Pricing Method under Different Mortality Models', *Scandinavian Actuarial Journal*, 2016 (2): 146-166.

Basellini, U., and Camarda, C. G. (2019) 'Modelling and Forecasting Adult Age-at-death Distributions', *Population Studies*, 73(1):1-20.

Basellini, U., Camarda, C. G., and Booth, H. (2023) Thirty Years On: A Review of the Lee–Carter Method for Forecasting Mortality, *International Journal of Forecasting*, 39(3): 1033-1049.

Basellini, U., Kjærgaard, S., and Camarda C. (2020) 'An Age-at-Death Distribution Approach to Forecast Cohort Mortality', *Insurance: Mathematics and Economics,* 91: 129-143

Bauer, D. (2006) 'An Arbitrage-Free Family of Longevity Bonds', Discussion Paper, University of Ulm.

Bauer, D., Benth, F. E., and Kiesel, R. (2010a) 'Modeling the Forward Surface of Mortality', Discussion Paper, University of Ulm.

Bauer, D., Börger, M., and Russ, J. (2010b) 'On the Pricing of Longevity-Linked Securities', *Insurance: Mathematics and Economics,* 46: 139-149.

Bauer, D., Börger, M., Russ J., and Zwiesler, H. J. (2008) 'The Volatility of Mortality', *Asia-Pacific Journal of Risk and Insurance*, 3: 172-199.

Bauer, D., Fasano, M., Russ, J., and Zhu, N. (2018) 'Evaluating Life Expectancy Evaluations', *North American Actuarial Journal,* 22: 198-209.

Bauer, D., and Kramer, F. (2007) 'Risk and Valuation of Mortality Contingent Catastrophe Bonds', Discussion Paper, University of Ulm

Bauer, D., and Ruβ, J. (2006) 'Pricing Longevity Bonds using Implied Survival Probabilities', Discussion Paper, University of Ulm.

Bayraktar, E., Milevsky, M., Promislow, D., and Young, V. (2009) 'Valuation of Mortality Risk via the Instantaneous Sharpe Ratio: Applications to Life Annuities', *Journal of Economic Dynamics and Control,* 3: 676-691.

Beard, R. E. (1971) 'Some Aspects of Theories of Mortality, Cause of Death Analysis, Forecasting and Stochastic Processes', *Biological Aspects of Demography*, 999:57–68.

Bégin, J. F., Boudreault, M., and Landry, T. (2025) 'Modelling Seasonal Mortality: An Age–Period–Cohort Approach', *Insurance Mathematics and Economics*; DOI: 10.1016/j.insmatheco.2025.103162

Bégin, J. F., Kapoor, N., and Sanders, B. (2023a) 'A New Approximation of Annuity Prices for Age–Period–Cohort Models', *European Actuarial Journal*; https://doi.org/10.1007/s13385-023-00370-4

Bégin, J. F., Sanders, B., and Xu, X. (2023b) 'Modeling and Forecasting Subnational Mortality in the Presence of Aggregated Data', *North American Actuarial Journal*; 10.1080/10920277.2023.2231996

Bégin, J. F., Sanders, B., and Zhou, W. (2024) 'On the Benefits of Pension Plan Consolidation: Understanding the Impact of Full Plan Mergers', *Annals of Actuarial Science*; 10.1017/S1748499524000150

Bell, A., and Jones, K. (2013) 'The Impossibility of Separating Age, Period and Cohort Effects', *Social Science and Medicine*, 93:163–165.

Bergeron-Boucher, M.-P., Canudas-Romo, V., Oeppen, J., Vaupel, J. W. (2017) 'Coherent Forecasts of Mortality with Compositional Data Analysis', *Demographic Research*, 37(1): 527-566.

Bergeron-Boucher, M.-P., Vázquez-Castillo, P., and Missov, T. I. (2024) 'A Modal Age at Death Approach to Forecasting Adult Mortality', *Population Studies*; 10.1080/00324728.2024.2310835

Bernanke, B. S. (2005) 'What Explains the Stock Market's Reaction to Federal Reserve Policy?', *Journal of Finance*, 60(3): 1221-1257.

Bernhardt, T., and Donnelly, C. (2019) 'Modern Tontine with Bequest: Innovation in Pooled Annuity Products', Insurance: Mathematics and Economics, 86(C): 168-188.

Berstein, S., and Morales, M. (2021) 'The Role of Longevity Insurance in Defined Contribution Pension Systems', *Insurance: Mathematics and Economics*, 99(C): 233-240.

Beutner, E., Reese, S., and Urbain, J. (2017) 'Identifiability Issues of Age-Period and Age-Period-Cohort Models of the Lee–Carter Type', *Insurance: Mathematics and Economics*, 75: 117-125.

Beyaztas, U., and Shang, H. L. (2022) 'Machine-Learning-Based Functional Time Series Forecasting: Application to Age-Specific Mortality Rates', *Forecasting*, 4, 394–408.

Bi, D., and Zeng, Y. (2025) Enhancing Actuarial Projections: A Factor-augmented Cohort Component Method for Forecasting Age- and Gender-specific Population, *Scandinavian Actuarial Journal*; DOI: 10.1080/03461238.2025.2592280

Biffis, E. (2005) 'Affine Processes for Dynamic Mortality and Actuarial Valuations', *Insurance: Mathematics and Economics,* 37: 443-468.

Biffis, E., and Blake, D. (2010) 'Securitizing and Tranching Longevity Exposures', *Insurance: Mathematics and Economics,* 46: 186-197

Biffis, E., and Blake, D. (2013) 'Informed Intermediation of Longevity Exposures', *Journal of Risk and Insurance,* 80: 559-584.

Biffis, E., and Blake, D. (2014) 'Keeping Some Skin in the Game: How to Start a Capital Market in Longevity Risk Transfers', *North American Actuarial Journal*, 18(1): 14-21.

Biffis, E., Denuit, M., and Devolder, P. (2010) 'Stochastic Mortality under Measure Changes', *Scandinavian Actuarial Journal,* 2010: 284-311.

Biffis, E., Lin, Y., and Milidonis, A. (2017) 'The Cross-Section of Asia-Pacific Mortality Dynamics: Implications for Longevity Risk Sharing', *Journal of Risk and Insurance*, 84(S1): 515-532.

Bisetti, E., and. Favero, C. A. (2014) 'Measuring the Impact of Longevity Risk on Pension Systems: The Case of Italy', *North American Actuarial Journal*, 18(1): 87-104.

Bjerre, D. S. (2022) 'Tree-Based Machine Learning Methods for Modeling and Forecasting Mortality', *ASTIN Bulletin*, 52(3): 765-787.

Black, F. (1976) 'The Pricing of Commodity Contracts', *Journal of Financial Economics*, 3: 167-179.

Blackburn, C., Hanewald, K., Olivieri, and Sherris, M. (2017) 'Longevity Risk Management and Shareholder Value for a Life Annuity Business', *ASTIN Bulletin*, 47 (1): 43-77.

Blackburn, C., and Sherris, M. (2013) 'Consistent Dynamic Affine Mortality Models for Longevity Risk Applications', *Insurance: Mathematics and Economics*, 53: 64–73.

Blake, D. (2018) 'Longevity: A New Asset Class', *Journal of Asset Management*, 19: 278–300.

Blake, D., Boardman, T., and Cairns, A. (2014) 'Sharing Longevity Risk: Why Governments Should Issue Longevity Bonds', *North American Actuarial Journal*, 18(1): 258-277.

Blake, D., and Burrows, W. (2001) 'Survivor Bonds: Helping to Hedge Mortality Risk', *Journal of Risk and Insurance,* 68(2): 339-48.

Blake, D., Cairns, A.J.G., Coughlan, G. D., Dowd, K. and MacMinn, R. (2013) 'The New Life Market', *Journal of Risk and Insurance,* 80: 501-558.

Blake, D., Cairns, A., and Dowd, K. (2006a) 'Living with Mortality: Longevity Bonds and Other Mortality-Linked Securities', *British Actuarial Journal,* 12: 153–197.

Blake, D., Cairns, A.J.G., Dowd, K. and MacMinn, R. (2006b) 'Longevity Bonds: Financial Engineering, Valuation and Hedging', *Journal of Risk and Insurance,* 73: 647-72.

Blake, D., Dowd, K., and Cairns, A.J.G. (2008) 'Longevity Risk and the Grim Reaper's Toxic Tail: The Survivor Fan Charts', *Insurance: Mathematics and Economics,* 42:1062-1068.

Blake, D., and Harrison, D. (2008) *And Death Shall Have No Dominion: Life Settlements and the Ethics of Profiting from Mortality*, Pensions Institute Report, July. Available at pensions-institute.org/DeathShallHaveNoDominion_Final_3July08.pdf.

Blanchard, O., Furceri, D., and Pescatori, A. (2014) 'A Prolonged Period of Low Real Interest Rates?' In C. Teulings and R. Baldwin (Eds.) *Secular Stagnation: Facts, Causes, and Cures*. London: Centre for Economic Policy Research.

Boateng, A. Y., Omari-Sasu, A. Y., and Boateng, M. (2024) 'Stochastic Mortality Models with Birth Cohort Effects in Older People: A Systematic Review', *African Journal of Empirical Research*, 5(4):1496-150

Bohl, D. K., Hughes, B. B., and Johnson, S. (2016) Understanding and Forecasting Demographic Risk and Benefits, Report for the Frederick S. Pardee Center for International Futures, Josef Korbel School of International Studies, University of Denver.

Bongaarts, J. (2005) 'Long-range Trends in Adult Mortality: Models and Projection Methods', *Demography*, 42(1): 23–49.

Boonen, T. J., and Chen, Y. (2025) 'VAR Model with Sparse Group LASSO for Multi-population Mortality Forecasting', *International Journal of Forecasting*; DOI: 10.1016/j.ijforecast.2025.03.004

Booth, H., Hyndman, R. J., Tickle, L., and de Jong, P. (2006) 'Lee-Carter Mortality Forecasting: A Multi-country Comparison of Variants and Extensions', *Demographic Research*, 15: 289-310.

Booth, H., Maindonald, J., and Smith. L. (2002a) 'Applying Lee-Carter under Conditions of Variable Mortality Decline', *Population Studies,* 56: 325-336.

Booth, H., Maindonald, J., and Smith. L. (2002b) 'Age-Time Interactions in Mortality Projection: Applying Lee-Carter to Australia', Working Papers in Demography, Australian National University.

Booth, H., and Tickle, L. (2008) 'Mortality Modelling and Forecasting: A Review of Methods', *Annals of Actuarial Science*, 1(2):3-43.

Börger, M., Freimann, A., and Ruß, J. (2023) 'On the Economics of the Longevity Risk Transfer Market', *Journal of Risk and Insurance*, 90(3): 597-632.

Börger, M., Freimann, A., and Ruß, J. (2021a) 'A Combined Analysis of Hedge Effectiveness and Capital Efficiency in Longevity Hedging', *Insurance: Mathematics and Economics*, 99(C): 309-326.

Börger, M., Ruß, J., and Schupp, J. (2021b) 'It Takes Two: Why Mortality Trend Modeling is More Than Modeling One Mortality Trend', *Insurance: Mathematics and Economics*, 99(C), 222-232.

Börger, M., and Schupp, J. (2018) 'Modeling Trend Processes in Parametric Mortality Models', *Insurance: Mathematics and Economics*, 78: 369-380.

Borio, C., and Disyatat, P. (2015) 'Capital Flows and the Current Account: Taking Financing (More) Seriously', *BIS Working Papers No. 525;* https://www.bis.org/publ/work525.htm

Börsch-Supan, A. (2006) 'Demographic Change, Saving and Asset Prices: Theory and Evidence', Mannheim Research Institute (MEA)

Boumezoued, A. (2021) 'Improving HMD Mortality Estimates with HFD Fertility Data', *North American Actuarial Journal*, 25(S1): S255-S279.

Boumezoued, A., and Elfassihi, A. (2021) 'Mortality Data Correction in the Absence of Monthly Fertility Records', *Insurance: Mathematics and Economics*, 99(C): 486-508.

Boumezoued, A., Hardy, H. L., El Karoui, N. and Arnold, S. (2018) 'Cause-of-Death Mortality: What can be Learned from Population Dynamics?', *Insurance: Mathematics and Economics*, 78: 301-315.

Boumezoued, A., Hoffmann, M., and Jeunesse, P. (2019) 'Nonparametric Adaptive Inference of Birth and Death Models in a Large Population Limit', arXiv preprint, arXiv:1903.00673.

Boumezoued, A., Hoffmann, M., and Jeunesse, P. (2020) 'A New Inference Strategy for General Population Mortality Tables', *ASTIN Bulletin*, 50(2):325-356.

Bozikas, A., Badounas, I., and Pitselis, G. (2022) 'Pricing Longevity Bonds under a Credibility Framework with Limited Available Data', *Risks*, 10: 96.

Bravo, J. M. (2011) 'Pricing Longevity Bonds Using Affine-Jump Diffusion Models', CEFAGE-UE Working Papers 2011_29, University of Evora.

Bravo, J. M. (2022) 'Pricing Participating Longevity-linked Life Annuities: A Bayesian Model Ensemble Approach', *European Actuarial Journal*, 12: 125-159.

Bravo, J. M., and Ayuso, M. (2021) 'Linking Pensions to Life Expectancy: Tackling Conceptual Uncertainty through Bayesian Model Averaging', *Mathematics*, 9(24)(3307):1-27.

Bravo, J. M., Ayuso, M., Holzmann, R., and Palmer, E. (2021) 'Addressing the Life Expectancy Gap in Pension Policy', *Insurance: Mathematics and Economics,* 99(C), 200-221.

Bravo, J. M., Ayuso, M., Holzmann, R., and Palmer, E. (2023) 'Intergenerational Actuarial Fairness when Longevity Increases: Amending the Retirement Age', *Insurance: Mathematics and Economics*, 113(C): 161-184.

Bravo, J. M., and El Mekkaoui de Freitas, N. (2018) 'Valuation of Longevity-Linked Life Annuities', *Insurance: Mathematics and Economics*, 78: 212-229.

Bravo, J. M., and Nunes, J. P. V. (2021) 'Pricing Longevity Derivatives via Fourier Transforms', *Insurance: Mathematics and Economics*, 96(C): 81-97.

Brockett, P. L., Chuang, S.-L., Deng, Y., and MacMinn, R. D. (2013) 'Incorporating Longevity Risk and Medical Information into Life Settlement Pricing', *Journal of Risk and Insurance,* 80: 799-826.

Broeders, D., Mehlkopf, R., and van Ool, A. (2021) 'The Economics of Sharing Macro-longevity Risk', Insurance: Mathematics and Economics, 99(C): 440-458.

Brouhns, N., Denuit, M., and Van Keilegom, I. (2005) 'Bootstrapping the Poisson Log-Bilinear Model for Mortality Forecasting', *Scandinavian Actuarial Journal*, 2005: 212–224.

Brouhns, N., Denuit, M., and Vermunt, J. K. (2002a) 'A Poisson Log-Bilinear Regression Approach to the Construction of Projected Lifetables', *Insurance: Mathematics and Economics,* 31: 373–393.

Brouhns, N., Denuit, M., and Vermunt, J. (2002b) 'Measuring the Longevity Risk in Mortality Projections', *Bulletin of the Swiss Association of Actuaries,* 2: 105–130.

Brown, J., and Warshawsky, M. (2013) 'The Life Care Annuity: A New Empirical Examination of an Insurance Innovation which Addresses Problems in the Markets for Life Annuities and Long-Term Care Insurance', *Journal of Risk and Insurance,* 80: 677-704.

Bruszas, S., Kaschützke, B., Maurer, R., and Siegelin, I. (2018) 'Unisex Pricing of German Participating Life Annuities—Boon or Bane for Customer and Insurance Company?', *Insurance: Mathematics and Economics*, 78: 230-245.

Brynjolfsson, E., and McAfee, A. (2014) *The Second Machine Age*. New York: W. W. Norton & Company.

Bugler, N., Maclean, K., Nicenko, V., and Tedesco, P. (2021) 'Reinsurance Side-Cars: The Next Stage in the Development of the Longevity Risk Transfer Market', *North American Actuarial Journal*, 25(S1): S25-S39.

Buckner, D., Dowd, K., and Hulley, H. (2023) 'A Market Consistent Approach to the Valuation of No Negative Equity Guarantees and Equity Release Mortgages', *Journal of Demographic Economics*, 89(3):349-372.

Buckner, D., Dowd, K., and Hulley, H. (2024) 'How Suitable are Equity Release Mortgages as Investments for Pension Funds?', *Geneva Papers on Risk and Insurance - Issues and Practice*, 49: 259-269.

Bufalo, M., and Nigri, A. (2024) 'Forecasting Vital Rates by a Trimodal Extension of the Flexible Generalized Skew Normal Probability Density Function', *Statistics: A Journal of Theoretical and Applied Statistics*; DOI: 10.1080/02331888.2024.2422376

Cadena, M., and Denuit, M. (2023) 'Mortality Projections for Higher Educational Attainment with Semi-Parametric Accelerated Hazard Relational Models', *Decisions in Economics and Finance*, 46(2): 569-582.

Cairns, A. J.G. (2011) 'Modelling and Management of Longevity Risk: Approximations to Survivor Functions and Dynamic Hedging', Insurance: Mathematics and Economics, 49(3): 438-453.

Cairns, A.J.G. (2013) 'Robust Hedging of Longevity Risk', *Journal of Risk and Insurance,* 80: 621-648.

Cairns, A.J.G., Blake, D, and Dowd K. (2006a) 'Pricing Death: Frameworks for the Valuation and Securitization of Mortality Risk', *ASTIN Bulletin,* 36: 79-120.

Cairns, A.J.G., Blake, D, and Dowd K. (2006b) 'A Two-Factor Model for Stochastic Mortality with Parameter Uncertainty: Theory and Calibration', *Journal of Risk and Insurance,* 73: 687-718.

Cairns, A.J.G., Blake, D., and Dowd, K. (2008) 'Modelling and Management of Mortality Risk: A Review', *Scandinavian Actuarial Journal*, 2-3, 79-113.

Cairns, A.J.G., Blake, D., Dowd, K., Coughlan, G.D., Epstein, D., and Khalaf-Allah, M. (2011a) 'Mortality Density Forecasts: An Analysis of Six Stochastic Mortality Models', *Insurance: Mathematics and Economics,* 48: 355-367.

Cairns, A. J. G., Blake, D., Dowd, K., Coughlan, G. D., Jones, O., and Rowney, J. (2022) A General Framework for Analysing the Mortality Experience of a Large Portfolio of Lives: With an Application to the UK Universities Superannuation Scheme, *European Actuarial Journal*, 12: 381–415.

Cairns, A.J.G., Blake, D. Dowd, K. Coughlan, G.D. and Khalaf-Allah, M. (2011b) 'Bayesian Stochastic Mortality Modelling for Two Populations', *ASTIN Bulletin,* 41: 29-59.

Cairns, A.J.G., Blake, D., Dowd, K., Coughlan, G.D., Epstein, D., Ong, A., and Balevich, I. (2009) 'A Quantitative Comparison of Stochastic Mortality Models using Data from England & Wales and the United States', *North American Actuarial Journal,* 13: 1-35.

Cairns, A. J., Blake, D., Dowd, K., and Kessler, A. R. (2016) 'Phantoms Never Die: Living with Unreliable Population Data', *Journal of the Royal Statistical Society: Series A (Statistics in Society)*, 179(4):975-1005.

Cairns, A.J.G., Blake, D., Kessler, A. R., and Kessler, M. (2020) 'The Impact of Covid-19 on Future Higher-Age Mortality', Pensions Institute Discussion Paper WP2007, 19 May; http://www.pensions-institute.org/wp-content/uploads/wp2007.pdf

Cairns, A.J.G., Blake, D., Kessler, A. R., Kessler, M. and Mathur, R. (2024a) 'Covid-19 Mortality: The Proportionality Hypothesis', *European Actuarial Journal*; DOI: 10.1007/s13385-024-00400-9

Cairns, A. J., Dowd, K., Blake, D., and Coughlan, G. D. (2014) 'Longevity Hedge Effectiveness: A Decomposition', *Quantitative Finance,* 14: 217-235.

Cairns, A. J. G., and El Boukfaoui, G. (2021) 'Basis Risk in Index Based Longevity Hedges: A Guide for Longevity Hedgers', *North American Actuarial Journal*, 25(S1): S97-S118.

Cairns, A. J. G., Kleinow, T., and Wen, J. (2024b) 'Drivers of Mortality: Risk Factors and Inequality', *Journal of the Royal Statistical Society Series A (General)*, 187(4): 989-1012.

Câmpeanu, C. A., and Meng, Y. (2026) 'An Age Grouping Framework for Multi-Population Mortality Modeling', *Risks*, 14(3):59

Cannon, E., Tonks, I., and Yuille, R. (2016) 'The Effect of the Reforms to Compulsion on Annuity Demand', *National Institute Economic Review*, No. 237, August, R47-R54.

Caraballo, T., Morillas, F., and Valero, J. (2022) 'On a Stochastic Nonlocal System with Discrete Diffusion Modeling Life Tables', *Stochastics and Dynamics*, 22(7), 2240017

Carannante, M., D'Amato, V., and Haberman, S. (2022) 'Covid-19 Accelerated Mortality Shocks and the Impact on Life Insurance: The Italian Situation', *Annals of Actuarial Science*, 16(3): 478-497.

Carannante, M., D'Amato, V., and Haberman, S. (2023) 'Effect of the Covid-19 Frailty Heterogeneity on the Future Evolution of Mortality by Stratified Weighting', *Journal of Demographic Economics,* 89(3):513-532.

Carannante, M., D'Amato, V., Haberman, S., and Menzietti, M. (2024a) 'Frailty-based Lee-Carter Family of Stochastic Mortality Models', *Quality & Quantity*, 58(6): 5081-5105.

Carannante, M., D'Amato, V., Menzietti, M., and Haberman, S. (2024b) 'Frailty-Based Mortality Models for Reserving for Longevity Risk', *Geneva Papers on Risk and Insurance - Issues and Practice*, 49: 320-339.

Carannante, M., D'Amato, V., and Di Palo, C. (2025) 'Prolonging Life by Vitagions: modelling of Mortality Improvement Shocks', *Insurance Mathematics and Economics*; DOI: 10.1016/j.insmatheco.2025.103198

Cardillo, G., Giordani, P., Levantesi, S., Nigri, A., and Spelta, A. (2023) 'Mortality Forecasting using the Four-way CANDECOMP/PARAFAC Decomposition', *Scandinavian Actuarial Journal*, 2023(9):1-17.

Carlson, C.J., Gregory F. Albery, G.F., Merow, C., Trisos, C. H., Zipfel, C. M., Eskew, E. A., Olival, K. J., Ross, N., and Bansal, S. (2022) 'Climate Change Increases Cross-Species Viral Transmission Risk', *Nature*, 607 555–562.

Chan, W.-S., Li, J. S.-H., and Li, J. (2014) 'The CBD Mortality Indexes: Modeling and Applications', *North American Actuarial Journal*, 18(1): 38-58.

Chandra, C. E., and Abdullah, S. (2022) 'Forecasting Mortality Trend of Indonesian Old Aged Population with Bayesian Method', *International Journal on Advanced Science, Engineering and Information Technology*, 12(2): 580-588.

Chang, C.-K., Yue, J. C., Chen, C.-J., and Chen, Y.-W. (2021) 'Mortality Differential and Social Insurance: A Case Study in Taiwan', *North American Actuarial Journal*, 25(S1): S582-S592.

Chang, L. and Shi, Y. (2023) 'Forecasting Mortality Rates with a Coherent Ensemble Averaging Approach', *ASTIN Bulletin*, 53(1): 2-28.
Chen A., Chen, Y., and Rach, M. (2025a) 'Dynamic Tonuity: Adapting Retirement Benefits to a Changing Environment', *Astin Bulletin*, 55(2):352-373
Chen A., Hieber P., and Klein J. K. (2019) 'Tonuity: A Novel Individual-Oriented Retirement Plan', *ASTIN Bulletin*, 49(1): 5–30.
Chen, A., Li, H., and Schultze, M. B. (2022a) 'Tail Index-linked Annuity: A Longevity Risk Sharing Retirement Plan', *Scandinavian Actuarial Journal*, 2022(2): 139-164.
Chen, A., Li, H., and Schultze, M. B. (2022b) 'Collective Longevity Swap: A Novel Longevity Risk Transfer Solution and its Economic Pricing', *Journal of Economic Behavior & Organization*, 201(1): 227-249.
Chen, A., Li, H., and Schultze, M. B. (2023a) 'Optimal Longevity Risk Transfer under Asymmetric Information', *Economic Modelling*, 120, 106179.
Chen, A., Müller, A., and Rach, M. (2025d) 'The Tontine Puzzle', *Journal of Mathematical Economics*, 121:103185
Chen, A., and Rach, M. (2019) 'Options on Tontines: An Innovative Way of Combining Tontines and Annuities', *Insurance: Mathematics and Economics*, 89(C): 182-192.
Chen, A., and Rach, M., and Sehner, T. (2020) 'On the Optimal Combination of Annuities and Tontines', *ASTIN Bulletin*, 50 (1): 95-129.
Chen, B., Zhang, L. and Zhao, L. (2010) 'On the Robustness of Longevity Risk Pricing', *Insurance: Mathematics and Economics,* 47: 358-373.
Chen, F.-Y, Yang, S. S., and Huang, H.-C. (2022) 'Modeling Pandemic Mortality Risk and its Application to Mortality-Linked Security Pricing', *Insurance: Mathematics and Economics*, 106: 341-363.
Chen, H., and Cox, S. H. (2009) 'Modeling Mortality with Jumps: Applications to Mortality Securitization', *Journal of Risk and Insurance,* 76: 727–751.
Chen, H., and Cummins, J. D. (2010) 'Longevity Bond Premiums: The Extreme Value Approach and Risk Cubic Pricing', *Insurance: Mathematics and Economics,* 46: 150-161.
Chen, H., Gao, J., and Zhu, W. (2023b) 'A Unified Framework for Insurance Demand and Mortality Immunization', *North American Actuarial Journal*, 28(2), 469–490.
Chen, H., MacMinn, R. D., and Sun, T. (2015) 'Multi-Population Mortality Models: A Factor Copula Approach', *Insurance: Mathematics and Economics*, 63:135–146.
Chen, H., MacMinn, R.D., and Sun, T. (2017) 'Mortality Dependence and Longevity Bond Pricing: A Dynamic Factor Copula Mortality Model with the GAS Structure', *Journal of Risk and Insurance*, 84(S1): 393-415.
Chen, H., Sherris, M., Sun, T., and Zhu, W. (2013) 'Living with Ambiguity: Pricing Mortality-Linked Securities with Smooth Ambiguity Preferences', *Journal of Risk and Insurance,* 80: 705-732.
Chen R.Y. and Millossovich P. (2018) 'Sex-Specific Mortality Forecasting for UK Countries: A Coherent Approach', *European Actuarial Journal*, 8(1): 69-95.
Chen, Y., and Khaliq, A. Q. M. (2022) 'Comparative Study of Mortality Rate Prediction Using Data-Driven Recurrent Neural Networks and the Lee–Carter Model', *Big Data and Cognitive Computing,* 6(4):134.

Chen, Y., Liu, W., and Zhao, Z. (2025b) 'Optimal Control Problem for Hybrid Pension Plans under Longevity Risk for Alpha-maxmin Expected Utility Minimization', *North American Journal of Economics and Finance*, 75(A): 102285.

Chen, Z., Feng, R., Li, H., and Yang, T. (2024) 'Coping with Longevity via Hedging: Fair Dynamic Valuation of Variable Annuities', *Insurance: Mathematics and Economics*, 117(C): 154-169.

Chen, Z., Li, H., Mao, Y., and Zhou, K. Q. (2025c) 'Learning from COVID-19: A Catastrophe Mortality Bond Solution in the Post-pandemic Era', *Insurance: Mathematics and Economics*, 123, 103113.

Chen, Z., Shi, L., and Shu, A. (2023c) 'Managing Mortality and Aging Risks with a Time-Varying Lee–Carter Model', *Healthcare*, 11(5):743.

Cheng, R., Shi, J., Loh, J. M., and Gao, G. (2025) 'Neural Networks for Simultaneous Modeling of Multi-population Mortality with Coherent Forecasts', *Scandinavian Actuarial Journal*; DOI: 10.1080/03461238.2025.2478439

Cheng, Z., Si, W., Xu, Z., and Xiang, K. (2022) 'Prediction of China's Population Mortality under Limited Data', *International Journal of Environmental Research and Public Health*, 19(19):12371.

Choulli, T., Daveloose, C., and Vanmaele, M. (2021) 'Mortality/Longevity Risk-Minimization with or without Securitization', *Mathematics*, 9(14): 1-27.

Christensen, K. and Vaupel. J. W. (1996) 'Determinants of Longevity: Genetic, Environmental and Medical Factors', *Journal of Internal Medicine*, 240(6): 333–341.

Chuang, S.-L., and Brockett, P. L. (2014) 'Modeling and Pricing Longevity Derivatives using Stochastic Mortality Rates and the Esscher Transforms', *North American Actuarial Journal*, 18(1): 22-37.

Chiu, M. C., Wang, L, and Wong, H. Y. (2025) 'Long-range Dependent Mortality Modeling with Cointegration', *Scandinavian Actuarial Journal*; DOI: 10.1080/03461238.2025.2503290

Clemente, G. P., Della Corte, F., and Nino, S. (2022) 'A Stochastic Model for Capital Requirement Assessment for Mortality and Longevity Risk, Focusing on Idiosyncratic and Trend Components', *Annals of Actuarial Science*, 16(3): 527-546.

Cocco, J.F. and Gomes, F.J. (2008) 'Hedging Longevity Risk', Discussion Paper, London Business School.

Cocco, J.F. and Gomes, F.J. (2012) 'Longevity Risk, Retirement Savings, and Financial Innovation', *Journal of Financial Economics,* 103: 507-529.

Cochrane, J. (2021) 'Low Interest Rates and Government Debt', speech prepared for the IGIER policy seminar, 11 January.

Coelho, E., and Nunes, L. C. (2011) 'Forecasting Mortality in the Event of a Structural Change', *Journal of the Royal Statistical Society: Series A (Statistics in Society),* 174: 713–736.

Coppola, M., Russolillo, M., and Simone, R. (2022) 'On the Evolution of the Gender Gap in Life Expectancy at Normal Retirement Age for OECD Countries', *Genus*, 78, 27.

Corsaro, S., Marino, Z., and Scognamiglio, S. (2024) 'Quantile Mortality Modelling of Multiple Populations via Neural Networks', *Insurance: Mathematics and Economics*, 116(C):114-133.

Costabile, M., Massabó, I., Russo, E., Staino, A., and Mamon, R., and Zhao, Y. (2025) 'A Lattice-based Approach for Life Insurance Pricing in a Stochastic Correlation Framework', *Mathematics and Computers in Simulation*, 235, 145-159.

Coughlan, G. D. (2025) 'Avoiding a Longevity Catastrophe: Harnessing Longevity Indices to Mitigate Individual, Institutional and Systemic Longevity Risks', *Insurance Mathematics and Economics*, 125:103153; DOI: 10.1016/j.insmatheco.2025.103153

Coughlan, G. D., Epstein, D., Sinha, A., and Honig. P. (2007) *q-Forwards: Derivatives for Transferring Longevity and Mortality Risks*, J.P. Morgan, London.

Coughlan, G. D., Khalaf-Allah, M. Ye, Y., Kumar, S., Cairns, A.J.G., Blake, D., and Dowd, K. (2011) 'Longevity Hedging 101: A Framework for Longevity Basis Risk Analysis and Hedge Effectiveness', *North American Actuarial Journal,* 15: 150-176.

Cowley, A., and Cummins, J. D. (2005) 'Securitization of Life Insurance Assets and Liabilities'*, Journal of Risk and Insurance,* 72: 193-226.

Cox, S. H., and Lin, Y. (2007) 'Natural Hedging of Life and Annuity Mortality Risks', *North American Actuarial Journal,* 11: 1-15.

Cox, S. H., Lin, Y., and Liu, S. (2021) 'Optimal Longevity Risk Transfer and Investment Strategies', *North American Actuarial Journal*, 25(S1): S40-S65.

Cox, S. H., Lin, Y., and Pedersen, H. (2010) 'Mortality Risk Modeling: Applications to Insurance Securitization', *Insurance: Mathematics and Economics,* 46: 242-253.

Cox, S. H., Lin, Y., and Shi, T. (2018) 'Pension Risk Management with Funding and Buyout Options', *Insurance: Mathematics and Economics*, 78: 183-200.

Cox, S. H., Lin, Y., Tian, R., and Yu, J. (2013a) 'Managing Capital Market and Longevity Risks in a Defined Benefit Pension Plan', *Journal of Risk and Insurance,* 80: 585-620.

Cox, S. H., Lin, Y., Tian, R., and Zuluaga, L. F. (2013b), 'Mortality Portfolio Risk Management', *Journal of Risk and Insurance,* 80: 853–890.

Cupido, K., Jevtić, P., and Paez, A. (2020) 'Spatial Patterns of Mortality in the United States: A Spatial Filtering Approach'*, Insurance*: *Mathematics and Economics*, 95(C): 28-38.

Cupido, K., Jevtić, P., and Boonen, T. J. (2024) 'Space, Mortality, and Economic Growth', Journal of Forecasting, 43(5): 1321-1337.

Currie, I.D. (2011) 'Modelling and Forecasting Mortality of the Very Old', *ASTIN Bulletin*, 41: 419-427.

Currie, I. D. (2016) 'On Fitting Generalized Linear and Non-Linear Models of Mortality', *Scandinavian Actuarial Journal*, 2016: 356-383.

Currie, I. D. (2020) 'Constraints, the Identifiability Problem and the Forecasting of Mortality', *Annals of Actuarial Science*, 14(2): 537–566.

Currie, I. D. (2023) 'A Black Box Approach to Fitting Smooth Models of Mortality', *Statistical Modelling*; 10.1177/1471082X231181165

Currie, I., Durbán, M., and Eilers, P. (2004) 'Smoothing and Forecasting Mortality Rates', *Statistical Modelling,* 4(4): 279–298.

Czado, C., A. Delwarde, and M. Denuit (2005) 'Bayesian Poisson Log-Linear Mortality Projections', *Insurance: Mathematics and Economics,* 36: 260-284.

Dagpunar, J. (2021) 'Closed-form Solutions for an Explicit Modern Ideal Tontine with Bequest Motive', Insurance: Mathematics and Economics, 100: 261-273.

Dahl, M. (2004) 'Stochastic Mortality in Life Insurance: Market Reserves and Mortality-Linked Insurance Contracts', *Insurance: Mathematics and Economics,* 35: 113-136.

Dahl, M., and Møller, T. (2006) 'Valuation and Hedging of Life Insurance Risks with Systematic Mortality Risk', *Insurance: Mathematics and Economics,* 39: 193-217.

Daly, L., and Hall, M. (2025) 'Mortality in Ireland and Northern Ireland 2000–2021 and the Joint Modelling of Irish and Northern Irish Life Tables', *European Actuarial Journal*; DOI: 10.1007/s13385-025-00420-z

D'Amato, V., Di Lorenzo, E., Haberman, S., Russolillo, M., and Sibillo, M. (2011) 'The Poisson Log-Bilinear Lee-Carter Model: Applications of Efficient Bootstrap Methods to Annuity Analyses', *North American Actuarial Journal,* 15: 315-333.

D'Amato, V., Di Lorenzo, E., Haberman, S., Sagoo, P,. and Sibillo, M. (2018a) 'De-Risking Strategy: Longevity Spread Buy-In', *Insurance: Mathematics and Economics*, 79: 124-136.

D'Amato, V., Di Lorenzo, E., Sibillo, M. (2018b) 'Dread Disease and Cause-Specific Mortality: Exploring New Forms of Insured Loans', *Risks*, *6*, 13.

D'Amato V., Haberman S., Piscopo G., and Russolillo M. (2012a) 'Modelling Dependent Data for Longevity Projections', *Insurance: Mathematics and Economics,* 51: 694-701.

D'Amato, V., Haberman, S., Piscopo, G., Russolillo, M., and Trapani, L. (2014) 'Detecting Common Longevity Trends by a Multiple Population Approach', *North American Actuarial Journal*, 18(1): 139-149.

D'Amato V., Haberman S., and Russolillo M. (2012b) 'The Stratified Sampling Bootstrap: An Algorithm for Measuring the Uncertainty in Forecast Mortality Rates in the Poisson Lee-Carter Setting', *Methodology and Computing in Applied Probability*, 14(1): 135-148.

Danesi, I. L., Haberman, S., and Millossovich, P. (2015) 'Forecasting Mortality in Subpopulations using Lee-Carter Type Models: A Comparison', *Insurance: Mathematics and Economics,* 62, 151–161.

Darkiewicz, G., and Hoedemakers, T. (2004) 'How the Cointegration Analysis can Help in Mortality Forecasting', Discussion Paper, Catholic University of Leuven.

Dastranj, R., and Kolář, M. (2025) 'Age-gender-country-specific Death Rates Modelling and Forecasting: A Linear Mixed-effects Model, *Scandinavian Actuarial Journal*; DOI: 10.1080/03461238.2025.2492181

Dawson, P., Blake, D., Cairns, A.J.G., and Dowd, K. (2010) 'Survivor Derivatives: A Consistent Pricing Framework', *Journal of Risk and Insurance,* 77: 579-96.

Dawson, P., Dowd, K., Cairns, A.J.G., and Blake, D. (2009) 'Options on Normal Underlyings with an Application to the Pricing of Survivor Swaptions', *Journal of Futures Markets*, 29(8): 757-774.

De Mori, L., Haberman, S., Millossovich, P., Zhu, R. (2025) 'Mortality Forecasting via Multi-task Neural Networks', *Astin Bulletin*; DOI: 10.1017/asb.2025.10

Debón, A., Chaves, L., Haberman, S., and Villa. F. (2017) 'Characterization of Between-group Inequality of Longevity in European Union Countries', *Insurance: Mathematics and Economics*, 75:151-65.

Debón, A., Haberman, S., and Piscopo, G. (2023) 'Multipopulation Mortality Analysis: Bringing Out The Unobservable With Latent Clustering', *Quality & Quantity*; 10.1007/s11135-023-01728-2

Debón, A., Haberman, S., and Piscopo, G. (2025) 'A Holistic Approach to Interpretable Modelling and Forecasting of Human Mortality by Gender and Country', *Annals of Operations Research*; DOI: 10.1007/s10479-025-06779-2

Debonneuil, E. (2010) 'Simple Model of Mortality Trends aiming at Universality: Lee Carter + Cohort', *Quantitative Finance Papers* 1003:1802, arXiv.org.
Debonneuil, E., Eyraud-Loisel, A., and Planchet, F. (2018a) 'Can Pension Funds Partially Manage Longevity Risk by Investing in a Longevity Megafund?', *Risks*, *6*, 67.
Debonneuil, E., Loisel, S., and Planchet, F. (2018b) 'Do Actuaries Believe in Longevity Deceleration?', *Insurance: Mathematics and Economics*, 78: 325-338.
Deelstra, G., Devolder, P., Roelants du Vivier, B. (2024) 'Impact of Correlation between Interest Rates and Mortality Rates on the Valuation of Various Life Insurance Products', *Astin Bulletin*; DOI: 10.1017/asb.2024.20
De Jong, P. and Ferris, S. (2019) 'SM Bonds – A New Product for Managing Longevity Risk', *Journal of Risk and Insurance*, 86(1): 121–149.
De Jong, P. and Tickle, L. (2006) Extending Lee–Carter Mortality Forecasting, *Mathematical Population Studies*, 13(1): 1–18.
De Jong, P., Tickle, L., and Xu, J. (2016) 'Coherent Modeling of Male and Female Mortality using Lee-Carter in a Complex Number Framework', *Insurance: Mathematics and Economics*, 71: 130-137.
De Jong, P., Tickle, L., and Xu, J. (2020) 'A More Meaningful Parameterization of the Lee-Carter Model', *Insurance: Mathematics and Economics*, 94(C): 1-8.
De Mori, L., Millossovich, P., Zhu, R., and Haberman, S. (2024) 'Two-Population Mortality Forecasting: An Approach Based on Model Averaging', *Risks*, 12(4): 1-17.
del Olmo, D. A., and Navarro, E. (2024) 'Revisiting Key Mortality Rate Models: Novel Findings and Application of CIR Processes to Describe Mortality Trends, *Rivista di Matematica per le Scienze Economiche e Sociali*, DOI: 10.1007/s10203-024-00481-x
Delbrouck, C., and Alonso-García, J. (2024) 'COVID-19 and Excess Mortality: An Actuarial Study', *Risks*, 12(4): 1-27.
Delwarde, A., Denuit, M., and Eilers, P. (2007) 'Smoothing the Lee-Carter and Poisson Log-Bilinear Models for Mortality Forecasting: A Penalised Log-likelihood Approach', *Statistical Modelling,* 7: 29-48.
Deng, Y., Brockett, P., and MacMinn, R. (2011) 'Pricing Life Settlements', Working Paper, *Center for Risk Management and Insurance*, University of Texas.
Deng, Y., Brockett, P., and MacMinn, R. (2012) 'Longevity/Mortality Risk Modeling and Securities Pricing', *Journal of Risk and Insurance,* 79: 697-721.
Denuit, M. M. (2009) 'An Index for Longevity Risk Transfer', *Journal of Computational and Applied Mathematics,* 230: 411-417.
Denuit, M. M., Devolder, P., and Goderniaux, A. (2007) 'Securitization of Longevity Risk: Pricing Survivor Bonds with Wang Transform in the Lee-Carter Framework', *Journal of Risk and Insurance,* 74: 87-113.
Denuit, M. M., Haberman, S., and Renshaw, A. (2015) 'Longevity-Contingent Deferred Life Annuities', *Journal of Pension Economics and Finance*, 14(3): 315-327.
Deprez, P., Shevchenko, P. V., and Wüthrich, M. V. (2017) 'Machine Learning Techniques for Mortality Modeling', *European Actuarial Journal*, 7(2): 337-352.
De Rosa, C., Luciano, E., and Regis, L. (2021) 'Geographical Diversification and Longevity Risk Mitigation in Annuity Portfolios', *ASTIN Bulletin*, 51(2): 375-410.
Devolder, P., Menzietti, M., and Diakite, K. (2025) 'Inter and Intra-generational Fairness for Public Pension Systems in Multi-population Mortality Models', *Scandinavian Actuarial Journal*; DOI: 10.1080/03461238.2025.2592288

Di Cesare, M., and Murphy, M. J. (2009) 'Forecasting Mortality, Different Approaches for Different Cause of Deaths? The Cases of Lung Cancer; Influenza, Pneumonia, and Bronchitis; and Motor Vehicle Accidents', *British Actuarial Journal*, 15(Supplement):185–211.

Diana, A., Wong, J. S. T, and Pittea, A. (2025) 'A Unified Bayesian Framework for Mortality Model Selection', *Annals of Actuarial Science*; DOI: 10.1017/S1748499525100146

Diao, L., Meng, Y., and Weng, C. (2021) 'A DSA Algorithm for Mortality Forecasting', *North American Actuarial Journal*, 25(3): 438-458.

Diao, L., Meng, Y., Weng, C., and Wirjanto, T. (2023) 'Enhancing Mortality Forecasting through Bivariate Model–Based Ensemble', *North American Actuarial Journal,* DOI: 10.1080/10920277.2023.2167832

Diaz, G., Debón, A., and Giner-Bosch, V. (2018) 'Mortality Forecasting in Colombia from Abridged Life Tables by Sex', *Genus,* 74, 15.

Di Lorenzo, E., Piscopo, G., Sibillo, M., Tizzano, R. (2022) 'Reverse Mortgage and Risk Profile Awareness: Proposals for Securitization', *Applied Stochastic Models in Business and Industry*, 38 (2): 353-369.

Di Palo, C. (2025) 'Decomposing Changes in Life Annuities', *European Actuarial Journal*, 10.1007/s13385-025-00409-8

Dimai, M. (2025a) 'Multi-population Mortality Modeling with Economic, Environmental and Lifestyle Variables', *Quality & Quantity*, 59(1): 153-205.

Dimai, M. (2025b) 'Clustering of Mortality Paths with the Hellinger Distance and Visualization through the DISTATIS Technique, *Journal of the Italian Statistical Society*; DOI: 10.1007/s10260-024-00770-0

Dimai, M. and Brabec, M. (2024) 'A Bayesian Model for Age at Death with Cohort Effects', *Demographic Research*, 51(2):1017-1058.

Djeundje, V.B., Haberman, S., Bajekal, M., and Lu, J. (2022) 'The Slowdown in Mortality Improvement Rates 2011–2017: A Multi-country Analysis', *European Actuarial Journal,* 12: 839–878.

Dodd, E., Forster, J. J., Bijak, J., and Smith, P. W. F. (2021) 'Stochastic Modelling and Projection of Mortality Improvements using a Hybrid Parametric/Semiparametric Age-period-cohort Model', *Scandinavian Actuarial Journal*, 2021(2): 134–155

Dong, F., and Wong, H. Y. (2015) 'Longevity Bond Pricing under the Threshold CIR Model', *Finance Research Letters*, 15: 195-207.

Dong, Z. M., Shang, H. L., Hui, F., and Bruhn, A. (2025) 'A Compositional Approach to Modeling Cause-specific Mortality with Zero Counts', *Annals of Actuarial Science*, DOI: 10.1017/S1748499524000320

Donnelly, C. (2014) 'Quantifying Mortality Risk in Small Defined-Benefit Pension Schemes', *Scandinavian Actuarial Journal*, 2014(1): 41–57.

Doukhan, P., and Rynkiewicz, J., and Salhi, Y. (2021) 'Optimal Neighborhood Selection for AR-ARCH Random Fields with Application to Mortality', *Stats*, 5(1): 1-26.

Dowd, K., Blake, D., and Cairns, A.J.G. (2011a) 'A Computationally Efficient Algorithm for Estimating the Distribution of Future Annuity Values under Interest-rate and Longevity Risks', *North American Actuarial Journal,* 15: 237-247.

Dowd, K., Blake, D., Cairns, and A.J.G., Dawson, P. (2006) 'Survivor Swaps', *Journal of Risk and Insurance,* 73: 1-17.

Dowd, K., Buckner, D., Blake, D., and Fry, J. (2019) 'The Valuation of No-Negative Equity Guarantees and Equity Release Mortgages', *Economics Letters*, 184, 108669.
Dowd, K., Cairns, A. J. G., and Blake, D. (2020) 'CBDX: A Workhorse Mortality Model from the Cairns-Blake-Dowd Family', *Annals of Actuarial Science*, 14(2): 445–460.
Dowd, K., Cairns, A. J. G., and Blake, D. (2021) 'Hedging Annuity Risks with the Age-Period-Cohort Two-Population Gravity Model', *North American Actuarial Journal*, 25(S1): S170-S182.
Dowd, K., Cairns, A.J.G., Blake, D., Coughlan, G.D., Epstein, D., and Khalaf-Allah, M. (2010a) 'Evaluating the Goodness of Fit of Stochastic Mortality Models', *Insurance: Mathematics and Economics,* 47: 255-265.
Dowd, K., Cairns, A.J.G., Blake, D., Coughlan, G.D., Epstein, D., and Khalaf-Allah, M. (2010b) 'Backtesting Stochastic Mortality Models: An *Ex-Post* Evaluation of Multi-Period-Ahead Density Forecasts', *North American Actuarial Journal,* 14: 281-298.
Dowd, K., Cairns, A.J.G., Blake, D., Coughlan, G.D., and Khalaf-Allah, M. (2011b) 'A Gravity Model of Mortality Rates for Two Related Populations', *North American Actuarial Journal,* 15: 334-356.
Dror, D. M. (2025) 'Breaking the Mortality Curve: Investment-Driven Acceleration in Life Expectancy and Insurance Innovation', *Risks,* 13(7):122
Dugravot, A., Fayosse, A., Dumurgier, J., Bouillon, K., Rayana, T., Schnitzler, A., Kivimaki, M., Sabia, S., and Singh-Manoux, A. (2019) 'Social Inequalities in Multimorbidity, Frailty, Disability, and Transitions to Mortality: A 24-year Follow-up of the Whitehall II Cohort Study', *The Lancet: Public Health*, 11 December, doi.org/10.1016/S2468-2667(19)30226-9.
Dutton, L., Pantelous, A. A., and Seklecka, M. (2019) 'The Impact of Economic Growth in Mortality Modelling for Selected OECD Countries', *Journal for Forecasting*, 39(3): 533-550.
Dyrting, S., and Taylor, A.J. (2023) 'Estimating Age-specific Mortality using Calibrated Splines', *Population Studies*; 10.1080/00324728.2023.2228297
Ediev, D. M. (2011) 'Robust Backward Population Projections Made Possible', *International Journal of Forecasting*, 27(4): 1241–1247.
Ediev, D. M. (2021) 'On the Existence and Uniqueness of the Remaining Life Expectancy in the Model of a Stable Population', *Mathematical Models and Computer Simulations*, 13(6): 964-970.
Enchev, V., Kleinow, T., and Cairns, A. (2017) 'Multi-Population Mortality Models: Fitting, Forecasting and Comparisons', *Scandinavian Actuarial Journal*, 2017(4): 319-342.
European Systemic Risk Board (2021) *Lower for Longer – Macroprudential Policy Issues arising from the Low Interest Rate Environment*, Joint Task Force of ESRB Advisory Technical Committee (ATC), ESRB Advisory Scientific Committee (ASC), and ESCB Financial Stability Committee (FSC).
Euthum, M., Scherer, M., and Ungolo, F. (2024) 'A Neural Network Approach for the Mortality Analysis of Multiple Populations: A Case Study on Data of the Italian Population', European Actuarial Journal; 10.1007/s13385-024-00377-5
Faragher, R. G.A., Freimann, A., and Ruß, J. (2026) 'Scanning the Horizon: Integrating Expert Knowledge into the Calibration of Stochastic Mortality Models', *Insurance Mathematics and Economics*; DOI: 10.1016/j.insmatheco.2026.103230

Feldstein, M., and Horioka, C. (1980) 'Domestic Saving and International Capital Flows', *Economic Journal,* 90 (358): 314–329.

Feliciangeli, M., Kerkhof, J., and Van Duffel, S. (2025) 'Socio-economic Mortality Curves: The Belgian Case', European Actuarial Journal; DOI: 10.1007/s13385-025-00424-9

Feng, B. M., Siu, J. h., and Zhou, K. Q. (2022) 'Green Nested Simulation via Likelihood Ratio: Applications to Longevity Risk Management', *Insurance Mathematics and Economics*, 106: 285-301.

Feng, R., Gan, G., and Zhang, N. (2022) 'Variable Annuity Pricing, Valuation, and Risk Management: A Survey', *Scandinavian Actuarial Journal*, 2022(10): 867-900.

Feng, R., Jing, X., and Ng, K. T. H. (2025) 'Optimal Investment-withdrawal Strategy for Variable Annuities under a Performance Fee Structure', *Journal of Economic Dynamics and Control*, 170(C); 10.1016/j.jedc.2024.105003

Ferrero, G., Gross, M., and Neri, S. (2019) 'On Secular Stagnation and Low Interest Rates: Demography Matters', *International Finance*, 22: 262-278.

Fokeer, O. D., and Narsoo, J. (2022) 'Evaluation of the Forecasting Accuracy of Stochastic Mortality Models: An Analysis of Developed and Developing Countries', *Communications in Statistics: Case Studies, Data Analysis and Applications*, 8(4): 1-29.

Ford, N., and Horioka, C. Y. (2016) 'The 'Real' Explanation of the PPP Puzzle', Institute of Social and Economic Research, Discussion Paper No. 969, Osaka University, Ibaraki, Osaka, Japan.

Ford, N., and Horioka, C. Y. (2017) The 'Real' Explanation of the Feldstein–Horioka Puzzle, *Applied Economics Letters*, 24 (20): 95-97.

Friedberg, L., and Webb, A. (2007) 'Life is Cheap: Using Mortality Bonds to Hedge Aggregate Mortality Risk', *B.E. Journal of Economic Analysis & Policy,* 7(1): Article 31.

Fu, W., Droms, S., Brewer, P, and Smith, B. R. (2025) Applying Markov-switching Bayesian Vector Autoregression to an Age-partitioned Lee–Carter Mortality Model, *European Actuarial Journal*; DOI: 10.1007/s13385-025-00415-w

Fuentes, O. M., Fullmer, R. K., and García-Huitrón, M. (2024) 'A Sustainable, Variable Lifetime Retirement Income Solution for the Chilean Pension System', *Geneva Papers on Risk and Insurance - Issues and Practice*, 49: 234-258.

Gaille, S., and Sherris, M. (2011) 'Modelling Mortality with Common Stochastic Long-Run Trends', *Geneva Papers on Risk and Insurance – Issues and Practice,* 36: 595-621.

Gao, G., and Shi, Y. (2021) 'Age-Coherent Extensions of the Lee–Carter Model, *Scandinavian Actuarial Journal*, 2021(10): 998-1016.

Gao, H., Mamon, R., Liu, X., and Tenyakov, A. (2015) 'Mortality Modelling with Regime-Switching for the Valuation of a Guaranteed Annuity Option', *Insurance: Mathematics and Economics*, 63: 108–120.

Garces, L.P., Gómez, F., and Tang, Q. (2026) 'Indifference Pricing of Mortality-linked Securities using Backward Stochastic Differential Equations', *Astin Bulletin*; DOI: 10.1017/asb.2026.10088

Garrido, J., Milhaud, X., Olympio, A., and Popp, M. (2024) Climate Risk and its Impact on Insurance, The DIALog research chair and CNP Assurances, Paris.

Garrido, J, Shang, Y., and Xu, R. (2024) 'LSTM-Based Coherent Mortality Forecasting for Developing Countries', *Risks*, 12(2):27.

Gasimova, K., Haberman, S., and Millossovich, P. (2024) 'Solvency Analysis of Deferred Annuities', *Rivista di Matematica per le Scienze Economiche e Sociali*; DOI: 10.1007/s10203-024-00452-2

Gbari, S., Poulain, M., Dal, L., and Denuit, M. (2017) 'Extreme Value Analysis of Mortality at the Oldest Ages: A Case Study Based on Individual Ages at Death', *North American Actuarial Journal,* 21(3): 397-416.

Gemmo, I., Rogalla, R., and Weinert, J.-H. (2020) 'Optimal Portfolio Choice with Tontines under Systematic Longevity Risk', *Annals of Actuarial Science*, 14(2): 302–315.

Ghalehjooghi, A. S., and Lyu, P. (2021) 'Socio-Economic Differentiation in Experienced Mortality Modelling and its Pricing Implications', *European Actuarial Journal,* 12(1): 161-188.

Gibbs, Z., Groendyke, C., Hartman, B., and Richardson, R. (2020) 'Modeling County-Level Spatio-Temporal Mortality Rates Using Dynamic Linear Models', *Risks*, 8(4):117.

Goes, J., Barigou, K., and Leucht, A. (2025) 'Bayesian Mortality Modelling with Pandemics: A Vanishing Jump Approach', *Journal of the Royal Statistical Society Series C Applied Statistics*; DOI: 10.1093/jrsssc/qlaf018

Gompertz, B. (1825) 'On the Nature of the Function Expressive of the Law of Human Mortality, and on a New Mode of Determining the Value of Life Contingencies', *Philosophical Transactions of the Royal Society,* 115: 513–585.

Gong, G. and Webb, A. (2010) 'Evaluating the Advanced Life Deferred Annuity: An Annuity People Might Actually Buy', *Insurance: Mathematics and Economics,* 46: 210-221.

Goodhart, C., and Pradhan, M. (2020) *The Great Demographic Reversal: Ageing Societies, Waning Inequality, and an Inflation Revival*, London: Palgrave Macmillan.

Gordon, R. J. (2016) *The Rise and Fall of American Growth: The U.S. Standard of Living since the Civil War,* Princeton, NJ: Princeton University Press.

Gourieroux, C, and Lu, Y. (2015) 'Love and Death: A Freund Model with Frailty', *Insurance: Mathematics and Economics*, 63: 191–203.

Gourieroux, C. and Monfort, A. (2008) 'Quadratic Stochastic Intensity and Prospective Mortality Tables', *Insurance: Mathematics and Economics,* 43: 174-184.

Gourinchas, P.-O., and Rey, H. (2019) 'Global Real Rates: A Secular Approach', Bank for International Settlements Working Paper No 793, June.

Gowen, O., Fosse, E., and Winship, C. (2023) 'Cross-Group Differences in Age, Period, and Cohort Effects: A Bounding Approach to the Gender Wage Gap', S*ociological Science*, 10: 731-768.

Gratton, L. and Scott, A. J. (2016) *The 100-Year Life – Living and Working in an Age of Longevity*, London: Bloomsbury.

Graziani, R., and Nigri, A. (2025) 'An Age–Period–Cohort Model in a Dirichlet Framework: A Coherent Causes of Death Estimation', *Insurance Mathematics and Economics*; DOI: 10.1016/j.insmatheco.2025.103194

Grossman, I., and Wilson, T. (2025) 'A Practitioner-Oriented Evaluation of Mortality Forecasting Methods: The Case of Australia', *Comparative Population Studies*, 50; DOI: 10.12765/CPoS-2025-07

Grozen, J. M., and Mamon, R. (2025) 'A Direct Approach in the Pricing Analysis and Risk Role Matching of a Guaranteed Annuity Option Under Correlated Risks', *American Journal of Mathematical and Management Sciences*, 1–23; https://doi.org/10.1080/01966324.2025.2509009

Grozen, J. M., and Mamon, R. (2026) 'Guaranteed Annuity Option Under Correlated and Regime-Switching Risks', *Risks*, 14(2):42.

Guibert, Q., Lopez, O., and Piette, P. (2019) 'Forecasting Mortality Rate Improvements with a High-dimensional VAR', *Insurance: Mathematics and Economics*, 88: 255-272.

Guibert, Q., Pincemin, G., and Planchet, F. (2025) 'Impact of Climate Change on Mortality: An Extrapolation of Temperature Effects Based on Time Series Data in France', *International Journal of Forecasting*; DOI: 10.1016/j.ijforecast.2025.07.004

Gungah, G., and Narsoo, J. (2022) 'A Novel EVT-modified Lee-Carter Model for Mortality Forecasting: An Application to Extreme Mortality Events, *Journal of Statistics and Management Systems*, 25(1): 211-243.

Guo, G., and Bauer, D. (2021) 'Different Shades of Risk: Mortality Trends Implied by Term Insurance Prices', *North American Actuarial Journal*, 25(S1): S156-S169.

Guo, Y., and Li, J S.-H. (2025a) 'Fast Estimation of the Renshaw-Haberman Model and its Variants', *European Actuarial Journal*; DOI: 10.1007/s13385-025-00407-w

Guo, Y., and Li, J S.-H. (2025b) 'Robust Parameter Estimation for the Lee-Carter Family: A Probabilistic Principal Component Approach', *Insurance Mathematics and Economics*; DOI: 10.1016/j.insmatheco.2025.103164

Gutterman, S., and Vanderhoof, I. T. (1998) 'Forecasting Changes in Mortality: A Search for a Law of Causes and Effects', *North American Actuarial Journal*, 2(4):135–138.

Haas, M., and Sunde, U. (2025) 'Decomposing Longevity: How Life Expectancy Changes Around the World' *The Journal of the Economics of Ageing*; DOI: 10.1016/j.jeoa.2025.100587

Haberman, S. (2023) 'A Rejoinder to "Thirty Years On: A Review of the Lee–Carter Method for Forecasting Mortality"', *International Journal of Forecasting*, 39(3): 1050-1052.

Haberman, S., and Renshaw, A. (2009) 'On Age-Period-Cohort Parametric Mortality Rate Projections', *Insurance: Mathematics and Economics,* 45: 255-270.

Haberman, S., and Renshaw, A. (2011) 'A Comparative Study of Parametric Mortality Projection Models', *Insurance: Mathematics and Economics,* 48: 35-55.

Haberman, S., and Renshaw, A. (2012) 'Parametric Mortality Improvement Rate Modelling and Projecting', *Insurance: Mathematics and Economics,* 50: 309–333.

Haberman, S., and Renshaw, A. (2013) 'Modelling and Projecting Mortality Improvement Rates using a Cohort Perspective', *Insurance: Mathematics and Economics,* 53: 150–168.

Hainaut, D. (2012) 'Multidimensional Lee-Carter Model with Switching Mortality Processes', *Insurance: Mathematics and Economics,* 50: 236-246.

Hainaut, D. (2018) 'A Neural-Network Analyzer for Mortality Forecast', *ASTIN Bulletin*, 48: 481-508.

Hainaut, D. (2023) 'A Calendar Year Mortality Model in Continuous Time', ASTIN Bulletin, 53(2): 351-376.

Hanbali, H. (2025) 'Mean-variance Longevity Risk-sharing for Annuity Contracts', *Insurance Mathematics and Economics*; 120(C): 207-235.

Hanbali, H., Denuit, M., Dhaene, J., and Trufin, J. (2019) 'A Dynamic Equivalence Principle for Systematic Longevity Risk Management', *Insurance: Mathematics and Economics*, 86(C): 158-167.

Hanewald, K. (2011) 'Explaining Mortality Dynamics: The Role of Macroeconomic Fluctuations and Cause of Death Trends', *North American Actuarial Journal,* 15: 290-314.

Hari, N., De Waegenaere, A., Melenberg, B., and Nijman, T. (2008) 'Estimating the Term Structure of Mortality', *Insurance: Mathematics and Economics,* 42: 492-504.

Harrison, D., and Blake, D. (2013) 'A Healthier Way to De-Risk: The Introduction of Medical Underwriting to the Defined Benefit De-risking Market', Pensions Institute, London; www.pensions-institute.org/reports/HealthierWayToDeRisk.pdf.

Hartzmark, S. M., and Shue, K. (2023) 'Counterproductive Impact Investing: The Impact Elasticity of Brown and Green Firms', January, *SSRN Electronic Journal*; DOI: 10.2139/ssrn.4359282

Hatzopoulos, P., and Haberman, S. (2009) 'A Parameterized Approach to Modeling and Forecasting Mortality', *Insurance: Mathematics and Economics,* 44: 103-123.

Hatzopoulos, P., and Haberman, S. (2011) 'A Dynamic Parameterization Modeling for the Age-Period-Cohort Mortality', *Insurance: Mathematics and Economics,* 49: 155–174.

He, L., Huang, F., Shi, J., and Yang, Y. (2021) 'Mortality Forecasting using Factor Models: Time-Varying or Time-Invariant Factor Loadings?', *Insurance: Mathematics and Economics*, 98(C): 14-34.

Heligman, L. and Pollard, J. H. (1980) 'The Age Pattern of Mortality', *Journal of the Institute of Actuaries*, 107(1): 49–80.

Henshaw, K., Constantinescu, C., and Menoukeu-Pamen, O. (2020) 'Stochastic Mortality Modelling for Dependent Coupled Lives', *Risks*, 8(1):17.

Hilton, J., Dodd, E., Forster, J. J., and Smith, P. W. F. (2019) 'Projecting UK Mortality by using Bayesian Generalized Additive Models', *Journal of the Royal Statistical Society. Series C: Applied Statistics*, 68(1): 29–49.

Hilton, J., Dodd, E., Forster, J. J., and Smith P.W.F. (2021) 'Modelling Frontier Mortality using Bayesian Generalised Additive Models', *Journal of Official Statistics*, 37(3): 569–589.

Hobcraft, J., Menken, J., and Preston, S. H. (1982) 'Age, Period and Cohort Effects in Demography: A Review', *Population Index*, 48 (1): 4–43.

Horioka, C. Y., and Ford, N. (2017) 'A Possible Explanation of the 'Exchange Rate Disconnect Puzzle': A Common Solution to Three Macroeconomic Puzzles?, *Applied Economics Letters*, 24 (13): 918-922.

Horneff, V., Maurer, R., and Mitchell, O. S. (2023) 'Fixed and Variable Longevity Income Annuities in Defined Contribution Plans: Optimal Retirement Portfolios taking Social Security into Account', *Journal of Risk and Insurance*, 90(4): 831-860.

Horneff, V., Maurer, R., Mitchell, O. S., and Rogalla, R. (2015) 'Optimal Life Cycle Portfolio Choice with Variable Annuities offering Liquidity and Investment Downside Protection', *Insurance: Mathematics and Economics*, 63: 91–107.

Horneff, W.J., Maurer, R.H., Mitchell, O.S., and Stamos, M.Z. (2009) 'Asset Allocation and Location Over the Life Cycle with Investment-Linked Survival-Contingent Payouts', *Journal of Banking and Finance*, 33: 1688-1699.

Horneff, W. J., Maurer, R., and Rogalla, R. (2010) Dynamic Portfolio Choice With Deferred Annuities', *Journal of Banking and Finance*, 34: 2652-2664.

Horneff, W.J., Maurer, R.H., and Stamos, M.Z. (2008) 'Life-Cycle Asset Allocation with Annuity Markets: Is Longevity Insurance A Good Deal?', *Journal of Economic Dynamics and Control,* 32: 3590 -3612.

Hsiao, H.-T., Wang, C.-W., Liu, I-C., and Kung, K.-L. (2024) 'Mortality Improvement Neural-Network Model with Autoregressive Effect', *Geneva Papers on Risk and Insurance-Issues and Practice*, 49(2): 363-383.

Hsieh, M.-H., Tsai, J. C., and Wang, J. L. (2021) 'Mortality Risk Management Under the Factor Copula Framework - With Applications to Insurance Policy Pools', *North American Actuarial Journal*, 25(S1): S119-S131.

Hsieh, M.-H., Wang, J. L., Chiu, Y.-F., and Chen, Y.-C. (2018) 'Valuation of Variable Long-Term Care Annuities with Guaranteed Lifetime Withdrawal Benefits: A Variance Reduction Approach', *Insurance: Mathematics and Economics*, 78: 246-254.

Huang, F., Maller, R., and Ning, X. (2020) 'Modelling Life Tables with Advanced Ages: An Extreme Value Theory Approach', *Insurance Mathematics and Economics*, 93: 95-115.

Huang, H., Milevsky, M., and Salisbury, T. S. (2009) 'A Different Perspective on Retirement Income Sustainability: The Blueprint for a Ruin Contingent Life Annuity (RCLA)', *Journal of Wealth Management*, 11: 89–96.

Huang, H., Milevsky, M., and Salisbury, T. S. (2012) 'Optimal Retirement Consumption with a Stochastic Force of Mortality', Papers 1205.2295, arXiv.org.

Huang, H., Milevsky, M., and Salisbury, T. S. (2017) 'Retirement Spending and Biological Age', *Journal of Economic Dynamics & Control*, 84: 58-76'

Huang, H.-C., Wang, C.-W., and Miao, Y.-C. (2011) 'Securitization of Crossover Risk in Reverse Mortgages', *Geneva Papers on Risk and Insurance – Issues and Practice,* 36: 622-647.

Huang, Z., Sherris, M., Villegas, A. M., and Ziveyi, J. (2022) 'Modelling USA Age-Cohort Mortality: A Comparison of Multi-Factor Affine Mortality Models', *Risks*, 10(9): 183.

Hunt, A., and Blake, D. (2014) 'A General Procedure for Constructing Mortality Models', *North American Actuarial Journal*, 18(1): 116-138.

Hunt, A., and Blake, D. (2015) 'Modelling Longevity Bonds: Analysing the Swiss Re Kortis Bond', *Insurance: Mathematics and Economics*, 63, 12–29.

Hunt, A., and Blake, D. (2016) *The Good, the Bad and the Healthy: The Medical Underwriting Revolution in the Defined Benefit De-risking Market*, Pensions Institute, January, www.pensions-institute.org/reports/GoodBadHealthy.pdf

Hunt, A., and Blake, D. (2017) 'Modelling Mortality for Pension Schemes', *ASTIN Bulletin*, 47(2): 481-508.

Hunt, A., and Blake, D. (2018) Identifiability, Cointegration and the Gravity Model', *Insurance: Mathematics and Economics*, 78: 360-368.

Hunt, A., and Blake, D. (2020a) 'Identifiability in Age/Period Mortality Models', *Annals of Actuarial Science*, 14(2): 461–499.

Hunt, A., and Blake, D. (2020b) 'Identifiability in Age/Period /Cohort Mortality Models', *Annals of Actuarial Science*, 14(2): 500–536.
Hunt, A., and Blake, D. (2021a) 'On the Structure and Classification of Mortality Models', *North American Actuarial Journal*, 25(S1): S215-S234.
Hunt, A., and Blake, D. (2021b) 'A Bayesian Approach to Modelling and Projecting Cohort Effects', *North American Actuarial Journal*, 25(S1): S235-S254.
Hunt, A., and Blake, D. (2021c) 'Forward Mortality Rates in Discrete Time I: Calibration and Securities Pricing', *North American Actuarial Journal*, 25(S1): S482-S507.
Hunt, A., and Blake, D. (2021d) 'Forward Mortality Rates in Discrete Time II: Longevity Risk and Hedging Strategies', *North American Actuarial Journal*, 25(S1): S508-S533.
Hunt, A., and Villegas, A. M. (2015) 'Robustness and Convergence in the Lee–Carter Model with Cohort Effects', *Insurance*: *Mathematics* and *Economics*, 64(C): 186-202.
Hunt, A., and Villegas, A. M. (2023) 'Mortality Improvement Rates: Modeling, Parameter Uncertainty, and Robustness', *North American Actuarial Journal*, 27:1, 47-73.
Huang, G., Guo, F., Zimmermann, K. F., Liu, L., Taksa, L., Cheng, Z., Tani, M., and Franklin, M. (2023a) 'The Effect of the COVID-19 Pandemic on Life Expectancy in 27 Countries', Scientific Reports (Nature), 13, 8911.
Huang, S., Tan, K. S., Zhang, J., and Zhu, W. (2023b) 'Epidemic Financing Facilities: Pandemic Bonds and Endemic Swaps', *North American Actuarial Journal*; 10.1080/10920277.2023.2256818
Hwang, J., and Kim, S. K. (2023) 'Unexpected Longevity, Intergenerational Policies, and Fertility', *Journal of Population Economics*, 36(3): 1607-1640; https://10.1007/s00148-023-00943-3
Hyndman, R., Booth, H., and Yasmeen, F. (2013) 'Coherent Mortality Forecasting the Product-Ratio Method with Functional Time Series Models', *Demography,* 50: 261-283.
Ignatieva, K., Song, A., Ziveyi, J. (2018) 'Fourier Space Time-Stepping Algorithm for Valuing Guaranteed Minimum Withdrawal Benefits in Variable Annuities under Regime-Switching and Stochastic Mortality', *ASTIN Bulletin*, 48(1): 139-169.
International Monetary Fund (2012), *The Financial Impact of Longevity Risk,* Chapter 4 of *Global Financial Stability Report*, April, Washington DC.
Jallbjørn, S., and Jarner, S. F. (2022) 'Sex Differential Dynamics in Coherent Mortality Models', *Forecasting*, 4(4):819-844.
Jallbjørn, S., Jarner, S. F., and Hansen, N. R. (2023) 'Forecasting, Interventions and Selection: The Benefits of a Causal Mortality Model', *European Actuarial Journal*; 10.1007/s13385-023-00372-2
Jang, C., Owadally, I., and Clare, A. (2024) 'Life-cycle Investment and Housing Decisions with Longevity Annuities and Reverse Mortgage', *Journal of Risk Management*, 35(2):141-185.
Janssen, F., van Wissen, L. J. G., Kunst, A. E. (2013) 'Including the Smoking Epidemic in Internationally Coherent Mortality Projections', *Demography*, 50(4):1341-62.
Jarner, S. r. F., and Kryger, E. M. (2011) 'Modelling Adult Mortality in Small Populations: The SAINT Model', *ASTIN Bulletin,* 41: 377-418.
Jarner, S. r. F., and Jallbjørn, S. (2020) 'Pitfalls and Merits of Cointegration-based Mortality Models', *Insurance: Mathematics and Economics*, 90: 80-93.

Jarner, S. r. F., and Jallbjørn, S. (2022) 'The SAINT Model: A Decade Later', *ASTIN Bulletin*, 52(2): 483-517.

Jen, S. (2007) Demographic Trends and the Financial Markets, Morgan Stanley Fixed Income Research, 20 September.

Jena, D., Swain, P. F., Tripathy, M. R., and Sarangi, P. K. (2023) 'Modelling and Forecasting of Age Specific Mortality Rates in India', *Demography India*, 52(1): 118-133.

Jevtić, P., Kwak, M., and Pirvu, T. A. (2021) 'Practical Partial Equilibrium Framework for Pricing of Mortality-linked Instruments in Continuous Time', *European Actuarial Journal*, 12(1): 249-273.

Jevtić, P., and Regis, L. (2019) 'A Continuous-Time Stochastic Model for the Mortality Surface of Multiple Populations', *Insurance: Mathematics and Economics*, 88: 181-195.

Jevtić, P., Qin, C., and Zhou, H. (2023) 'Multi-population Mortality Modeling with Lévy Processes'*, Decisions in Economics and Finance,* 46(2): 583-609.

Jiao, Y., Salhi, Y., and Wang, S. (2022) 'Dynamic Bivariate Mortality Modelling', *Methodology and Computing in Applied Probability*, 24(3): 917–938.

Joint Forum (2013). *Longevity Risk Transfer Markets: Market Structure, Growth Drivers and Impediments, and Potential Risks*. Joint Forum of the Basel Committee on Banking Supervision, International Organization of Securities Commissions, and International Association of Insurance Supervisors, c/o Bank for International Settlements, Basel, Switzerland, December. Available at www.bis.org/publ/joint34.pdf.

Jones, P. M., Minton, J., and Bell, A. (2023) Methods for Disentangling Period and Cohort Changes in Mortality Risk over the Twentieth Century: Comparing Graphical and Modelling Approaches, *Quality & Quantity*, 57: 3219–3239.

Kabuche, D., Sherris, M., and Villegas, A. M., and Ziveyi, J. (2024) 'Pooling Functional Disability and Mortality in Long-term Care Insurance and Care Annuities: A Matrix Approach for Multi-state Pools, *Insurance Mathematics and Economics*, 116: 165–188.

Kallestrup-Lamb, M., Kjaergaard, S., and Rosenskjold, C. P. T. (2020) 'Insight into Stagnating Adult Life Expectancy: Analyzing Cause of Death Patterns across Socioeconomic Groups', *Health Economics*, 29(2): 1728-1743.

Kallestrup-Lamb, M., and Laursen, N. S. (2024) 'Longevity Hedge Effectiveness using Socioeconomic Indices', *Insurance: Mathematics and Economics*; 114(C): 242-251.

Kang, K., Liu, Y., Li J. S.-H., and Chan, W.-C. (2018) 'Mortality Forecasting for Multiple Populations: An Augmented Common Factor Model with a Penalized Log-Likelihood', *Communications in Statistics: Case Studies, Data Analysis and Applications*, 4 (3-4): 118-141.

Karabarbounis, L., and Neiman, B. (2014) 'Capital Depreciation and Labour Shares around the World: Measurement and Implications', NBER Working Paper No. 20606.

Katsiferis, A., Bhatt, S., Mortensen, L.H., Mishra, S., Jensen, M.K., Westendorp. R.G.J. (2023) 'Machine Learning Models of Healthcare Expenditures Predicting Mortality: A Cohort Study of Spousal Bereaved Danish Individuals', *PLoS One*, 18(8):e0289632.

Katsiferis, A., Bhatt, S., Mortensen, L. H., Mishra, S., Westendorp, R. G. J. (2023) 'Sex Differences in Health Care Expenditures and Mortality after Spousal Bereavement: A Register-Based Danish Cohort Study, *PLoS One*, 18(3): e0282892.

Kessler, A. (2021) 'New Solutions to an Age-Old Problem: Innovative Strategies for Managing Pension and Longevity Risk', *North American Actuarial Journal*, 25(S1): S7-S24.

Kessler, A. (2023) 'Resilience in a Time of Crisis: How Covid-19 Pandemic Insights are Supporting a Vibrant Longevity Risk Transfer Market', *Journal of Demographic Economics*, 89(3):313-327.

Kessy, S. R., Sherris, M, Villegas, A. M., and Ziveyi, J. (2022) 'Mortality Forecasting using Stacked Regression Ensembles', *Scandinavian Actuarial Journal,* 2022(7): 591-62.

Kiley, M. T. (2020) 'The Global Equilibrium Real Interest Rate: Concepts, Estimates and Challenges', *Annual Review of Financial Economics*, 12: 305-326.

Kjærgaard, S., Ergemen, Y. E., Bergeron-Boucher, M. P., Oeppen, J., and Kallestrup-Lamb, M. (2020) 'Longevity Forecasting by Socio-economic Groups using Compositional Data Analysis', *Journal of the Royal Statistical Society Series A: Statistics in Society*, 183(3), 1167-1187.

Kjærgaard, S., Ergemen, Y. E., Kallestrup-Lamb, M., Oeppen, J., and Lindahl-Jacobsen, R. (2019) 'Forecasting Causes of Death by Using Compositional Data Analysis: The Case of Cancer Deaths', *Journal of the Royal Statistical Society Series C: Applied Statistics*, 68(5): 1351-1370.

Kleinow, T. (2015) 'A Common Age Effect Model for the Mortality of Multiple Populations', *Insurance: Mathematics and Economics*, 63: 147–152.

Kleinow, T., and Cairns, A. (2013) 'Mortality and Smoking Prevalence: An Empirical Investigation in Ten Developed Countries' *British Actuarial Journal*, 18: 452-466.

Kleinow, T., and Richards, S. J. (2017) 'Parameter Risk in Time-Series Mortality Forecasts', *Scandinavian Actuarial Journal*, 2017(9): 804-828.

Kogure, A., Fushimi, T., and Kamiya, S. (2021) 'Mortality Forecasts for Long-Term Care Subpopulations with Longevity Risk: A Bayesian Approach', *North American Actuarial Journal,* 25(S1): S534-S544.

Kogure, A., and Kurachi, Y. (2010) 'A Bayesian Approach to Pricing Longevity Risk Based on Risk-Neutral Predictive Distributions', *Insurance: Mathematics and Economics* 46: 162-172.

Kogure, A., Li, J., and Kamiya, S. (2014) 'A Bayesian Multivariate Risk-Neutral Method for Pricing Reverse Mortgages', *North American Actuarial Journal*, 18(1): 242-257.

Kogure, A., and Takamatsu, Y. (2024) 'Bayesian Projection of Cohort Healthy Life Expectancies with Long-Term Care Insurance Data', *Japanese Journal of Statistics and Data Science*; DOI: 10.1007/s42081-024-00253-2

Koichubekov, B. Omarkulov, B. , Mukhanova, M., and Zakirova, R. (2025) 'Age-Specific Mortality Forecasting in Kazakhstan: Alternative Approaches to the Lee–Carter Model', *IJERPH*, MDPI, 22(3): 1-22.

Koijen, R.S.J., Nijman, T.E., and Werker, B.J.M. (2011) 'Optimal Annuity Risk Management', *Review of Finance*, 15: 799-833.

Koissi, M., Shapiro, A., and Hognas, G. (2006) 'Evaluating and Extending the Lee-Carter Model for Mortality Forecasting: Bootstrap Confidence Interval', *Insurance: Mathematics and Economics,* 38: 1–20.

Kuang, D., Nielsen, B., and Nielsen, J. (2008) 'Forecasting with the Age-Period-Cohort Model and the Extended Chain-Ladder Model', *Biometrika,* 95: 987-991.

Kularatne, T. D., Li, J., and Shi, Y. (2022) 'Forecasting Mortality Rates with a Two-Step LASSO-Based Vector Autoregressive Model', *Risks*, 10(11):219.

Kung, K.-L., Hsieh, M.-H., Peng, J.-L., Tsai, C. J., and Wang, J. L. (2021a) 'Explaining the Risk Premiums of Life Settlements', *Pacific-Basin Finance Journal*, 68: 101574.

Kung, K.-L., Liu, I-C., and Wang, C.-W. Wang (2021b) 'Modeling and Pricing Longevity Derivatives using the Skellam Distribution', *Insurance: Mathematics and Economics*, 99: 341-354.

Kung, K.-L., MacMinn , R. D., Kuo, W., and Tsai, C. J. (2022) 'Multi-Population Mortality Modeling: When the Data is Too Much and Not Enough', *Insurance: Mathematics and Economics*, 103: 41-55.

Kurtbegu, E. (2018) 'Replicating Intergenerational Longevity Risk Sharing in Collective Defined Contribution Pension Plans using Financial Markets', *Insurance: Mathematics and Economics*, 78: 286-300.

Lakehal, A., Metiri, F., and Remita, M. R. (2026) 'Modelling and Projecting Mortality of the Elderly Population: Comparison of Classical and Coherent Models', *Asia Pacific Journal of Mathematics*, 13:39

Lam, K. K., and Wang, B. (2024) 'Random Cohort Effects and Smooth Structures for Mortality Modelling and Forecasting: A Mixed-effects Gaussian Process Time Series Approach', *Communication in Statistics - Theory and Methods*; DOI: 10.1080/03610926.2024.2422879

Lane, M. (2011) 'Longevity Risk from the Perspective of the ILS Markets', *Geneva Papers on Risk and Insurance – Issues and Practice,* 36: 501-515.

Landriault, D., Li, B., Li, H., and Zhang, Y. (2026) 'Contract Structure and Risk Aversion in Longevity Risk Transfers', *Insurance Mathematics and Economics*; DOI: 10.1016/j.insmatheco.2026.103251

Lee, C., Hong, J., and Kim, S. (2021) 'Feasibility Assessment of Longevity Swap for the Korean Life Annuity Market', *Communications for Statistical Applications and Methods*, 28:655-671.

Lee, R. D. and Carter, L. R. (1992) 'Modeling and Forecasting U.S. Mortality', *Journal of the American Statistical Association*, 87(419): 659–671.

Lee, Y.-T. Kung, K.-L., and Liu, I-C. (2018) 'Profitability and Risk Profile of Reverse Mortgages: A Cross-System and Cross-Plan Comparison', *Insurance: Mathematics and Economics*, 78: 255-266.

Leng, X., and Peng, L. (2016) 'Inference Pitfalls in Lee-Carter Model for Forecasting Mortality', *Insurance: Mathematics and Economics*, 70: 58–65.

Leong, Y.-Y., and Yue, J. C. (2026) 'A Spatial Approach to Model Mortality Rates', Journal of Forecasting; DOI: 10.1002/for.70156

Lesné, S., Koh, M.-T., Kotilinek, L., Kayed, R., Glabe, C. G., Yang, A., Gallagher, M., and Ashe, K. H. (2006) 'A Specific Amyloid-β Protein Assembly in the Brain Impairs Memory', *Nature*, 440: 352–357.

Leung, M., Fung, M. C., and O'Hare, C. (2018) 'A Comparative Study of Pricing Approaches for Longevity Instruments', *Insurance: Mathematics and Economics*, 82, 95-116.

Leung, M., Li, Y., Pantelous, A. A. and Vigne, S. A. (2021) 'Bayesian Value-at-Risk Backtesting: The Case of Annuity Pricing', *European Journal of Operational Research*, 293(2): 786-801.

Levantesi, S., Lizzi, M. and Nigri, A. (2024) 'Enhancing Diagnostic of Stochastic Mortality Models Leveraging Contrast Trees: An Application on Italian Data', *Quality & Quantity*, 58(2): 1565-1581.

Levantesi, S., Nigri, A., and Piscopo, G. (2020) 'Longevity Risk Management through Machine Learning: State of the Art', *Insurance Markets and Companies*, 11(1):11-20.

Li, H. (2018) 'Dynamic Hedging of Longevity Risk: The Effect of Trading Frequency', *ASTIN Bulletin*, 48(1): 197-232.

Li, H., and Chen, H. (2022) 'Hierarchical Mortality Forecasting with EVT Tails: An Application to Solvency Capital Requirement', *International Journal of Forecasting*; 10.1016/j.ijforecast.2022.08.007

Li, H., De Waegenaere, A., and Melenberg, B. (2015a) 'The Choice of Sample Size for Mortality Forecasting: A Bayesian Learning Approach', *Insurance: Mathematics and Economics*, 63, 153–168.

Li, H., De Waegenaere, A., and Melenberg, B. (2017a) 'Robust Mean–Variance Hedging of Longevity Risk', *Journal of Risk and Insurance*, 84(S1): 459-475.

Li, H., and Hyndman, R. J. (2021) 'Assessing Mortality Inequality in the US: What can be said about the Future?, *Insurance: Mathematics and Economics*, 99(C): 152-162.

Li, H., Li, H., Lu, Y., and Panagiotelis, A. (2019) 'A Forecast Reconciliation Approach to Cause-of-Death Mortality Modeling', *Insurance: Mathematics and Economics*, 86: 122-133.

Li, H., Liu, H., Tang, Q., and Yuan, Z. (2023) 'Pricing Extreme Mortality Risk in the Wake of the COVID-19 Pandemic', *Insurance Mathematics and Economics*, 108(C): 84-106.

Li, H., and Lu, Y. (2017) 'Coherent Forecasting of Mortality Rates: A Sparse Vector-autoregression Approach, *ASTIN Bulletin*, 47, 563-600.

Li, H., Lu, Y., and Lyu, P. (2021) 'Coherent Mortality Forecasting for Less Developed Countries', *Risks*, 9: 151.

Li, H., and O'Hare, C. (2017) 'Semi-Parametric Extensions of the Cairns–Blake–Dowd Model: A One-Dimensional Kernel Smoothing Approach', *Insurance: Mathematics and Economics*, 77, 166–176.

Li, H., O'Hare, C., and Vahid, F. (2016) 'Two Dimensional Kernel Smoothing of Mortality Surface: An Evaluation of Cohort Strength', *Journal of Forecasting*, 35(6): 553-563.

Li, H., O'Hare, C., and Vahid, F. (2017b) 'A Flexible Functional Form Approach To Mortality Modeling: Do We Need Additional Cohort Dummies?', *Journal of Forecasting*, 36, 357-367.

Li, H., O'Hare, C., and Zhang, X. (2015b) 'A Semi-Parametric Panel Approach to Mortality Modeling', *Insurance: Mathematics and Economics*, 61, 264-270. ]

Li, H., and Shi, Y. (2021a) 'Mortality Forecasting with an Age-Coherent Sparse VAR Model', *Risks*, *9*(2), 35.

Li, H., and Shi, Y. (2021b) 'Forecasting Mortality with International Linkages: A Global Vector-autoregression Approach', *Insurance: Mathematics and Economics*, 100(C): 59-75.

Li, H., Tan, K. S., Tuljapurkar, S., and Zhu, W. (2021a) 'Gompertz Law Revisited: Forecasting Mortality with a Multi-factor Exponential Model', *Insurance: Mathematics and Economics*, 99(C): 268-281.

Li, H., and Tang, Q. (2019) 'Analyzing Mortality Bond Indexes via Hierarchical Forecast Reconciliation', *ASTIN Bulletin*, 49 (3): 823-846.

Li, H., Zhou, R., and Ji, M. (2023) 'Nonlinear Modeling of Mortality Data and Its Implications for Longevity Bond Pricing', *Risks*, 11: 207.
Li, J. (2013) 'A Poisson Common Factor Model for Projecting Mortality and Life Expectancy Jointly for Females and Males', *Population Studies*, 67(1):111-26.
Li, J. (2023) 'A Model Stacking Approach for Forecasting Mortality', *North American Actuarial Journal*, 27(3): 530-545.
Li, J. (2024) 'Bayesian Modelling of Best-performance Healthy Life Expectancy', *Journal of Population Research*, 41, 8.
Li, J., and Kogure, A. (2021) 'Bayesian Mixture Modelling for Mortality Projection', *Risks*, *9*(4), 76.
Li, J., Lee, M, and Guthrie, S. (2021b) 'A Double Common Factor Model for Mortality Projection Using Best-Performance Mortality Rates As Reference', *ASTIN Bulletin*, 51(2): 349 – 374.
Li, J., Li, J., Tan, C., and Tickle, L. (2019) 'Assessing Basis Risk in Index-Based Longevity Swap Transactions', *Annals of Actuarial Science*, 13(1), 166-197.
Li, J., Liu, L., and Butt, A. (2024a) 'A Systematic Vector Autoregressive Framework for Modeling and Forecasting Mortality', *Journal of Forecasting*, 43(6): 2279-2297.
Li, J., Tickle, L., and Parr, N. (2016) 'A Multi-population Evaluation of the Poisson Common Factor Model for Projecting Mortality Jointly for Both Sexes', *Journal of Population Research*, 33: 333–60.
Li, J., Wang, M., Liu, J., and Tickle, L. (2024b) 'Ensemble Interval Forecasts of Mortality', *Scandinavian Actuarial Journal*; DOI: 10.1080/03461238.2024.2444565
Li, J. S.-H. (2010) 'Pricing Longevity Risk with the Parametric Bootstrap: A Maximum Entropy Approach', *Insurance: Mathematics and Economics,* 47: 176-186.
Li, J. S.-H., and Chan, W.-S. (2011) 'Time-Simultaneous Prediction Bands: A New Look at the Uncertainty involved in Forecasting Mortality', *Insurance: Mathematics and Economics,* 49: 81-88.
Li, J. S.-H., Chan, W., and Cheung, S. (2011) 'Structural Changes in the Lee-Carter Mortality Indexes: Detection and Implications', *North American Actuarial Journal,* 15: 13–31.
Li, J. S.-H., Chan, W., and Zhou, R. (2017c) 'Semicoherent Multipopulation Mortality Modeling: The Impact on Longevity Risk Securitization', *Journal of Risk and Insurance*, 84(3):1025-1065.
Li, J. S.-H., and Hardy, M. R. (2011) 'Measuring Basis Risk involved in Longevity Hedges', *North American Actuarial Journal,* 15: 177-200.
Li, J. S.-H., Hardy, M., and Tan, K. (2009) 'Uncertainty in Mortality Forecasting: An Extension to the Classic Lee-Carter Approach', *ASTIN Bulletin*, 39: 137–164.
Li, J. S.-H., Li, J., Balasooriya, U., and Zhou, K. Q. (2021) 'Constructing Out-of-the-Money Longevity Hedges Using Parametric Mortality Indexes', *North American Actuarial Journal,* 25(S1): S341-S372.
Li, J. S.-H., Liu, Y., and Chan, W.-C. (2023) 'Hedging Longevity Risk under Non-Gaussian State-Space Stochastic Mortality Models: A Mean-Variance-Skewness-Kurtosis Approach', *Insurance: Mathematics and Economics*, 113(C): 96-121.
Li, J. S.-H., and Luo, A. (2012) 'Key q-Duration: A Framework for Hedging Longevity Risk', *ASTIN Bulletin*, 42: 413–452.

Li, J. S.-H., Zhou, K. Q., Zhu, X., Chan, W.-C., and Chan, F. W.-H. (2020a) 'A Bayesian Approach to Developing a Stochastic Mortality Model for China', *Journal of the Royal Statistical Society: Series A (Statistics in Society)*, 182: 1523-1560.

Li, J. S.-H., Zhou, R., and Hardy, M. R. (2015c) 'A Step-By-Step Guide To Building Two-Population Stochastic Mortality Models', *Insurance: Mathematics and Economics*, 63: 121–134.

Li, J. S.-H., Zhou, R., Liu, Y., Graziani, G., Hall, R. D., Haid, J., Peterson, A., and Laurence Pinzur, L. (2020b), Drivers of Mortality Dynamics: Identifying Age/Period/Cohort Components of Historical US Mortality Improvements', *North American Actuarial Journal*, 24(2):228–250.

Li, L., Li, H., and Panagiotelis, A. (2025a) 'Boosting Domain-specific Models with Shrinkage: An Application in Mortality Forecasting', *International Journal of Forecasting*, 41(1): 191-207.

Li, N., and Lee, R. D. (2005) 'Coherent Mortality Forecasts for a Group of Populations: An Extension of the Lee-Carter Method', *Demography,* 42: 575–594.

Li, N., Lee, R. D., and Gerland P. (2013) 'Extending the Lee-Carter Method to Model the Rotation of Age Patterns of Mortality Decline for Long-term Projections', *Demography*, 50: 2037–2051.

Li, R., Zhou, R., and Pitt, D. (2025b) 'Beyond Annual Data: Mortality Forecasting with Mixed Frequency Data', *Insurance Mathematics and Economics*; DOI: 10.1016/j.insmatheco.2025.103172

Li, S., Hardy, H. L., Sherris, M. and Villegas, A. M. (2022) 'A Managed Volatility Investment Strategy for Pooled Annuity Products', *Risks*, 10: 121.

Li, X. (2025) 'Hedging Longevity Risk with Longevity Bonds: Modeling, Design, and Valuation', *Advances in Economics Management and Political Sciences*, 221(1):35-40.

Li, Z., and Kara, A. (2022) 'Pension De-risking Choice and Firm Risk: Traditional Versus Innovative Strategies', *International Review of Financial Analysis*, 81: 102064.

Li, Z., Shao, A. W., and Sherris, M. (2017d) 'The Impact of Systematic Trend and Uncertainty on Mortality and Disability in a Multistate Latent Factor Model for Transition Rates', *North American Actuarial Journal,* 21 (4): 594-610.

Lin, T., and Tsai, C. C.-L. (2014) 'Applications of Mortality Durations and Convexities in Natural Hedges', *North American Actuarial Journal*, 18(3), 417–442.

Lin, T., and Tsai, C. C.-L. (2020a) 'Natural Hedges with Immunization Strategies of Mortality and Interest Rates', *ASTIN Bulletin*, 50 (1): 155-185.

Lin, T., and Tsai, C. C.-L. (2020b) 'Hedging Mortality/Longevity Risks for Multiple Years, *North American Actuarial Journal,* 24(1): 118-140.

Lin, T., and Tsai, C. C.-L. (2022) 'Hierarchical Bayesian Modeling of Multi-country Mortality Rates', *Scandinavian Actuarial Journal*, 2022(1):1-24.

Lin, T., and Tsai, C. C.-L. (2023) 'A New Option for Mortality-Interest Rates', *Journal of Futures Markets,* 43(2): 273-293.

Lin, T., Tsai, C. C.-L., and Cheng, H.-W. (2023) 'Asset Liability Management of Longevity and Interest Rate Risks: Using Survival–Mortality Bonds', *North American Actuarial Journal*, 27(1): 74-95.

Lin, T., and Tzeng, L. (2010) 'An Additive Stochastic Model of Mortality Rates: An Application to Longevity Risk in Reserve Evaluation', *Insurance: Mathematics and Economics,* 46: 423-435.

Lin, T.-J. C, Lee, Y.-S., Li, M.-R., and Tzeng, J. (2021) 'Applications of the Dynamic System and Differential Equations to Taiwan Mortality', *International Journal of Computing Science and Mathematics*, 13(3): 245- 266.

Lin, Y., and Cox, S. (2005) 'Securitization of Mortality Risks in Life Annuities', *Journal of Risk and Insurance,* 72: 227-252.

Lin, Y., Liu, S., and Yu, J. (2013), 'Pricing Mortality Securities with Correlated Mortality Indexes', *Journal of Risk and Insurance,* 80: 921–948.

Lin, Y., MacMinn, R. D., and Tian, R. (2015) 'De-Risking Defined Benefit Plans', *Insurance: Mathematics and Economics*, 63: 52–65.

Lin, Y., MacMinn, R.D., Tian, R., and Yu, J. (2017a) 'Pension Risk Management in the Enterprise Risk Management Framework', *Journal of Risk and Insurance*, 84(S1): 345-365.

Lin, Y., MacMinn, R.D., and Shi, T. (2023) 'Do Pension Buyouts Help or Hurt Employees (Retirees)?', *Journal of Risk and Insurance*, DOI: 10.1111/jori.12423

Lin, Y., and Shi, T., (2026) 'The Big Thaw: Unfreeze Defined Benefit Pension with Cash Balance Plans', *Insurance Mathematics and Economics*; DOI: 0.1016/j.insmatheco.2026.103245

Lin, Y., Shi, T., and Arik, A. (2017b) 'Pricing Buy-Ins and Buy-Outs', *Journal of Risk and Insurance*, 84(S1): 367-392.

Lin, Y., Tan, K. S., Tian, R., and Yu, J. (2014) 'Downside Risk Management of a Defined Benefit Plan Considering Longevity Basis Risk', *North American Actuarial Journal*, 18(1): 68-86.

Liu, C., and Shi, Y. (2023) 'Extensions of the Lee-Carter Model to Project the Data-Driven Rotation of Age-Specific Mortality Decline and Forecast Coherent Mortality Rates', Journal of Forecasting, 42(4): 813-834.

Liu, J. J. (2021) 'A Study on Link Functions for Modelling and Forecasting Old-Age Survival Probabilities of Australia and New Zealand', *Risks*, *9*(1), 11.

Liu, Q., Ling, C., Li, D., and Peng, L. (2019) 'Bias-Corrected Inference for a Modified Lee–Carter Mortality Model', *ASTIN Bulletin*, 49 (2): 433-455.

Liu, Y., and Li, J. S.-H. (2016) 'It's All in the Hidden States: A Longevity Hedging Strategy with an Explicit Measure of Population Basis Risk', *Insurance: Mathematics and Economics*, 70: 301-319.

Liu, Y., and Li, J. S.-H. (2017) 'The Locally Linear Cairns–Blake–Dowd Model: A Note on Delta–Nuga Hedging of Longevity Risk, *ASTIN Bulletin*, 47 (1): 79-151.

Liu, Y., and Li, J. S.-H. (2018) 'A Strategy for Hedging Risks Associated with Period and Cohort Effects using q-Forwards', *Insurance: Mathematics and Economics*, 78: 267-285.

Liu, Y., and Li, J. S.-H. (2021) 'An Efficient Method for Mitigating Longevity Value-at-Risk', *North American Actuarial Journal,* 25(S1): S309-S340.

Liu, Y., and Li, J. S.-H. (2023) 'Disentangling Trend Risk and Basis Risk with Functional Time Series', *Risks*, 11(12): 208.

Lizzi, M. (2024) 'A Contrast-Tree-Based Approach to Two-Population Models', *Risks*, 12(10):152

Lledó, J., Pavía, J. M., and Salas, J. S. (2023) 'An Alternative Approach to Manage Mortality Catastrophe Risks under Solvency II', *Risk Management*, 25: 16.

Longevity Basis Risk Working Group (2014) 'Longevity Basis Risk: A Methodology for Assessing Basis Risk', Institute and Faculty of Actuaries (IFoA) and the Life and Longevity Markets Association (LLMA), London (Authors: Haberman, S., Kaishev, V., Villegas, A., Baxter, S., Gaches, A., Gunnlaugsson, S., and Sison, M.).

Lourés, C. R., and Cairns, A. J. G. (2020) 'Mortality in the US by Education Level', *Annals of Actuarial Science*, 14(2): 384–419.

Lourés, C. R., and Cairns, A. J.G. (2021) 'Cause of Death Specific Cohort Effects In U.S. Mortality', *Insurance: Mathematics and Economics*, 99(C): 190-199.

Lu, Q., Hanewald, K., and Wang, X. (2021) 'Subnational Mortality Modelling: A Bayesian Hierarchical Model with Common Factors', *Risks*, *9(*11), 203.

Lu, Y., and Zhu, D. (2023) 'Modelling Mortality: A Bayesian Factor-Augmented VaR (FAVaR) Approach, *ASTIN Bulletin*, 53(1):29-61.

Ludkovski, M., Risk, J., and Zail, H. (2018) 'Gaussian Process Models for Mortality Rates and Improvement Factors', *ASTIN Bulletin*, 48 (3): 1307-1347.

Ludkovski, M. (2026) 'Gaussian Process Models in Actuarial Science', *Annals of Actuarial Science*; DOI: 10.1017/S1748499526100244

Lyu, P., De Waegenaere, A., and Melenberg, B. (2021) 'A Multi-Population Approach to Forecasting All-Cause Mortality Using Causes-of-Death Mortality Data', *North American Actuarial Journal,* 25(S1): S421-S456.

Lyu, P., Li, J. S.-H., and Zhou, K. Q. (2023) 'Socioeconomic Differentials in Mortality: Implications on Index-Based Longevity Hedges', *Scandinavian Actuarial Journal*, 2023(4): 359-387.

MacMinn, R., and Brockett, P. (2017) 'On the Failure (Success) of the Markets for Longevity Risk Transfer', *Journal of Risk and Insurance*, 84(S1): 273-277.

MacMinn, R., Lin, Y., and Shi, T. (2023) 'Buy-ins, Buy-outs, Longevity Bonds, and the Creation of Value', *Journal of Demographic Economics*, 89(3):329-347.

MacMinn, R., and Richter, A. (2018) 'The Choice of Trigger in an Insurance Linked Security: The Mortality Risk Case', *Insurance: Mathematics and Economics*, 78: 174-182.

MacMinn, R. D., and Zhu, N. (2017) 'Hedging Longevity Risk in Life Settlements Using Biomedical Research-Backed Obligations', *Journal of Risk and Insurance*, 84(S1): 439-458.

MacMinn, R. D., and Zhu, N. (2021) 'Hedging Longevity Risk: Does the Structure of the Financial Instrument Matter?', *North American Actuarial Journal,* 25(S1): S373-S364.

Maffra, S. A., Armstrong, J., Pennanen, T. (2021) 'Stochastic Modeling of Assets and Liabilities with Mortality Risk', *Scandinavian Actuarial Journal*, 2021(8): 695-725.

Maggistro, R., Marino, M., and Olivieri, A. (2026) 'A Markov Ageing-based Multi-state Group Self-annuitisation', *Astin Bulletin*; DOI: 10.1017/asb.2026.10095

Mankiw, G. N., and Weil, D. N. (1989). 'The Baby Boom, the Baby Bust and the Housing Market', *Regional Science and Urban Economics*, 19: 235-258.

Marino, M., Levantesi, S., and Nigri, A. (2023) 'A Neural Approach to Improve the Lee-Carter Mortality Density Forecasts', *North American Actuarial Journal*, 27(1): 148-165.

Masters, R. K., Aron, L. Y., and Woolf, S. H. (2022) 'Changes in Life Expectancy between 2019 and 2021 in the United States and 21 Peer Countries', Medrxiv.org; https://www.medrxiv.org/content/10.1101/2022.04.05.22273393v4

Mavros, G., Cairns, A. J. G., Streftaris G., and Kleinow, T. (2017) 'Stochastic Mortality Modeling: Key Drivers and Dependent Residuals', *North American Actuarial Journal,* 21 (3): 343-368.

Maurer, R, Mitchell, O. S. Rogalla, R., and Kartashov, V. (2013) 'Lifecycle Portfolio Choice with Systematic Longevity Risk and Variable Investment-Linked Deferred Annuities', *Journal of Risk and Insurance,* 80: 649-676.

Mayhew, L. (2023) 'Counting the Cost of Inequality', *Journal of Demographic Economics,* 89(3): 395-418.

Mayhew, L., Chan, M. S., and Cairns A. J.G. (2024) 'The Great Health Challenge – Levelling Up in the UK', *Geneva Papers on Risk and Insurance - Issues and Practice*, 49: 270-294.

Mayhew, L.**,** Harper, G., and Villegas, A. M. (2020) 'An Investigation into the Impact of Deprivation on Demographic Inequalities in Adults', *Annals of Actuarial Science*, 14(2): 358–383.

Mayhew, L.**,** Rickayzen, B., and Smith, D. (2021) 'Flexible and Affordable Methods of Paying for Long-Term Care Insurance', *North American Actuarial Journal*, 25(S1): S196-S214.

Mayhew, L., and Smith, D. (2011) 'Human Survival at Older Ages and the Implications for Longevity Bond Pricing', *North American Actuarial Journal,* 15: 248-265.

Mayhew, L., and Smith, D. (2014) 'Gender Convergence in Human Survival and the Postponement of Death', *North American Actuarial Journal*, 18(1): 194-216.

Mayhew, L., and Smith, D. (2021) 'An Investigation into Inequalities in Adult Lifespan', *North American Actuarial Journal*, 25(S1): S545-S565.

Mayhew, L., Smith, D., and Wright, D. (2018) 'The Effect of Longevity Drift and Investment Volatility on Income Sufficiency in Retirement', *Insurance: Mathematics and Economics*, 78: 201-211.

Mazonas, P.M., Stallard, P. J. E., and Graham, L. (2011) 'Longevity Risk in Fair Valuing Level-Three Assets in Securitized Portfolios', *Geneva Papers on Risk and Insurance – Issues and Practice,* 36: 516-543.

McCarthy, D. (2018) 'A Cohort-based Analysis of US Mortality Rates Project Rapid Improvements in Old-age Mortality', https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3088688.

McCarthy, D., and Wang, P-L. (2021a) 'An Analysis of Period and Cohort Mortality Shocks in International Data', *North American Actuarial Journal,* 25(S1): S385-S409.

McCarthy, D., and Wang, P.-L. (2021b) 'Pooling Mortality Risk in Eurozone State Pension Liabilities: An Application of a Bayesian Coherent Multi-Population Cohort-Based Mortality Model', *Insurance: Mathematics and Economics*, 99(C): 459-485.

McCarthy, D., and Wang, P.-L. (2023) 'Mortality Postponement and Compression at Older Ages in Human Cohorts', *PLoS One*, 18(3): e0281752.

McNicholl, G. (2021) 'Review of Goodhart and Pradhan', *Population and Development Review*, 47, 859-863

McNown, R., and Rogers, A. (1992) 'Forecasting Cause-Specific Mortality using Time Series Methods', *International Journal of Forecasting*, 8(3): 413–432.

Medford, A. (2021) 'Modeling Best Practice Life Expectancy Using Gumbel Autoregressive Models', *Risks*, *9*(3), 51.

Meng, Y., Diao, L., and Weng, C. (2025) 'Mortality Prediction via Age-specific Band Selection', *Scandinavian Actuarial Journal*; DOI: 10.1080/03461238.2025.2537925

Meese, R., and Rogoff, K. (1983) 'Empirical Exchange Rate Models of the Seventies: Do They Fit Out of Sample?', *Journal of International Economics*, 14: 3-24.

Menoncin, F. (2008) 'The Role of Longevity Bonds in Optimal Portfolios', *Insurance: Mathematics and Economics,* 42: 343-358.

Michaelson, A., and Mulholland, J. (2014) 'Strategy for Increasing the Global Capacity for Longevity Risk Transfer: Developing Transactions that Attract Capital Markets Investors', *Journal of Alternative Investments,* 17 (1): 18–27.

Mitchell, D., Brockett, P., Mendoza-Arriaga, R., and Muthuraman. K. (2013) 'Modeling and Forecasting Mortality Rates', *Insurance: Mathematics and Economics*, 52(2): 275–285.

Milevsky, M. A. (2005) 'Real Longevity Insurance with a Deductible: Introduction to Advanced-life Delayed Annuities (ALDA)', *North American Actuarial Journal*, 9: 109–22.

Milevsky, M. A. (2020) 'Calibrating Gompertz in Reverse: What is your Longevity-risk-adjusted Global Age?', *Insurance: Mathematics and Economics*, 92:147-161.

Milevsky, M.A., and Promislow, S.D. (2001) 'Mortality Derivatives and the Option to Annuitize', *Insurance: Mathematics and Economics,* 29: 299-318.

Milevsky, M. A., and Salisbury, T. S. (2015) 'Optimal Retirement Income Tontines', *Insurance: Mathematics and Economics,* 64: 91–105.

Milevsky, M.A. and Young,V.R. (2007) 'Annuitization and Asset Allocation', *Journal of Economic Dynamics and Control,* 31: 3138-3177.

Milidonis, A., and Efthymiou, M. (2017) 'Mortality Leads and Lags', *Journal of Risk and Insurance*, 84(S1): 495-514.

Milidonis, A., Lin, Y., and Cox, S. H. (2011) 'Mortality Regimes and Pricing', *North American Actuarial Journal,* 15: 266-289.

Mitchell, D., Brockett, P., Mendoza-Arriaga, R., and Muthuraman, K. (2013) 'Modeling and Forecasting Mortality Rates', *Insurance: Mathematics and Economics,* 52: 275–285.

Mitsuda, D., and Shimizu,Y. (2024) 'Mortality Prediction using Survival Energy Models with Functional Data Analysis', *Japanese Journal of Statistics and Data Science*; 10.1007/s42081-024-00245-2

Miyata, A., and Matsuyama, N. (2022) 'Extending the Lee–Carter Model with Variational Autoencoder: A Fusion of Neural Network and Bayesian Approach', *ASTIN Bulletin*, 52(3): 789-812.

Mok, K., K., K., Tan, C. I., Zhang, J., and Shi, Y. (2024) 'Mortality Modelling with Arrival of Additional Year of Mortality Data: Calibration and Forecasting', *Demographic Research*, 50:797-826.

Mrad, F., Hamdi, H., Naoui, K., and Abid, I. (2023) 'The GMWB guarantee embedded in Life Insurance Contracts: Fair Value Pricing Problem', *Finance Research Letters*, 51: 103327.

Murphy, M. (2010) 'Re-Examining the Dominance of Birth Cohort Effects on Mortality', *Population and Development Review,* 36: 365–90.

Murphy, M., and Di Cesare M. (2012) 'Use of an Age-Period-Cohort Model to Reveal the Impact of Cigarette Smoking on Trends in Twentieth Century Adult Cohort Mortality in England & Wales', *Population Studies,* 66: 259–77.

Murray, R., Johnson, B., Hart, M., and Nawaz, S. (2022) Longevity Over The Next Decade, *Life Risk News*, 1(8): December; liferisk.news/longevity-over-the-next-decade)

Navarro, E., and Atance, D. (2024) 'A Simplified Model for Measuring Longevity Risk for Life Insurance Products', *Financial Innovation*, 10(64); 10.1186/s40854-023-00515-0.

Navarro, E., and Requena, P. (2023) 'Impact of Covid-19 on Spanish Mortality Rates in 2020 by Age and Sex', *Journal of Public Health*, DOI: 10.1093/pubmed/fdad023

Neves, C., Fernandes, C., and Hoeltgebaum, H. (2017) 'Five Different Distributions for the Lee–Carter Model of Mortality Forecasting: A Comparison using GAS Models, *Insurance: Mathematics and Economics*, 75, 48-57.

Ngai, A., and Sherris, M. (2011) 'Longevity Risk Management for Life and Variable Annuities: The Effectiveness of Static Hedging using Longevity Bonds and Derivatives', *Insurance: Mathematics and Economics,* 49: 100-114.

Nguyen, H., Sherris, M., Villegas, A. M., and Ziveyi, J. (2024) 'Scenario Selection with LASSO Regression for the Valuation of Variable Annuity Portfolios', *Insurance: Mathematics and Economics*; 10.1016/j.insmatheco.2024.01.006

Nielsen, B., and Nielsen, J. (2014) 'Identification and Forecasting in Mortality Models', *The Scientific World Journal*, 2104: Article 347043.

Nigri, A., Barbi, E., and Levantesi, S. (2021) 'The Relationship Between Longevity and Lifespan Variation', *Journal of the Italian Statistical Society*, 31(3): 481-493.

Nigri, A., Levantesi, S., Marino, M., Scognamiglio, S., and Perla, F. (2019) 'A Deep Learning Integrated Lee–Carter Model', *Risks*, 7(1), 33.

Njenga, C.N., and Sherris, M. (2011) 'Longevity Risk and the Econometric Analysis of Mortality Trends and Volatility', *Asia-Pacific Journal of Risk and Insurance,* 5(2), 1-54.

Njenga, C.N., and Sherris, M. (2020) 'Modeling Mortality with a Bayesian Vector Autoregression', *Insurance: Mathematics and Economics, 94*(C): 40-57.

Nusselder, W. J., De Waegenaere, A. M. B., Melenberg, B., Lyu, P., and Valverde, J. R. R. (2022) 'Future Trends of Life Expectancy by Education in the Netherlands', *BMC Public Health*, 22: 1664.

Obstfeld, M. (2025) 'Natural and Neutral Real Interest Rates: Past and Future', NBER Working Paper 31949; http://www.nber.org/papers/w31949

Obstfeld, M., and Rogoff, K. (2000) 'The Six Major Puzzles in International Macroeconomics: Is There a Common Cause?', in Bernanke, B., and Rogoff, K. (eds.), *NBER Macroeconomics Annual 2000*, MIT Press, 15: 339–390.

Odhiambo, J. (2023) 'Deep Learning Incorporated Bühlmann Credibility in the Modified Lee-Carter Mortality Model', *Mathematical Problems in Engineering*, 2023: 8543909

Odhiambo, J., Weke, P., Ngare, P. (2021) 'A Deep Learning Integrated Cairns-Blake-Dowd (CBD) Sytematic Mortality Risk Model', *Journal of Risk and Financial Management*, 14(6): 1-12.
Odhiambo, J. O., Weke, P. G. O., Ngare, P., Naryongo, R., and Sewe, S. (2022) 'Poisson Incorporated Credibility Regression Modelling of Systematic Mortality Risk for Populations with Finite Data', *Mathematical Problems in Engineering*, 2022: 1753542.
OECD (2022) 'Strengthening Asset-backed Pension Systems in a Post-COVID World', OECD Publishing, Paris; https://doi.org/10.1787/288cb3cf-en.
Oeppen, J., and Vaupel, J. W. (2002) 'Broken Limits to Life Expectancy', *Science*, 296(5570):1029-31.
O'Hare, C., and Li, Y. (2012) 'Identifying Structural Breaks in Stochastic Mortality Models', Discussion Paper, Monash University.
O'Hare, C., and Li, Y. (2017) 'Mortality Models of Mortality Rates: Analysing the Residuals', *Applied Economics*, 49: 5309-5323.
Olivieri, A., and Pitacco E. (2008) 'Assessing the Cost of Capital for Longevity Risk', *Insurance: Mathematics and Economics,* 42: 1013-1021.
Olivieri, A., and Pitacco E. (2020) 'Linking Annuity Benefits to the Longevity Experience: Alternative Solutions', *Annals of Actuarial Science*, 14(2): 316–337.
Olivieri, A., and Pitacco E. (2022) 'Time Restrictions on Life Annuity Benefits: Portfolio Risk Profiles', *Risks*, 10: 164.
Olivieri, A., and Tabakova, D. (2024) 'Stochastic Assessment of Special-rate Life Annuities', *Rivista di Matematica per le Scienze Economiche e Sociali*; DOI: 10.1007/s10203-024-00476-8
Olivieri, A., Thirurajah, S., and Ziveyi, J. (2022) 'Target Volatility Strategies for Group Self-Annuity Portfolios', *ASTIN Bulletin*, 52(2): 591-617.
Olshansky, S.J., Willcox, B.J., Demetrius, L., Beltrán-Sánchez, H. (2024) 'Implausibility of Radical Life Extension in Humans in the Twenty-first Century', *Nature Aging*; https://doi.org/10.1038/s43587-024-00702-3
Orlova, N. (2021) 'Rising Inequality in Life Expectancy by Socioeconomic Status', *North American Actuarial Journal*, 25(S1): S566-S581.
Ortiz, C. E., Stone, C. A., and Zissu, A. (2023) 'The Shock of COVID-19 and the Shock of Rapid Vaccine Development on the Value of Senior Life Settlement Contracts', *Risk Management and Insurance Review*; 10.1111/rmir.12251
Orwat-Acedańska, A. (2023) 'Accuracy of Small Area Mortality Prediction Methods: Evidence from Poland', *Journal of Population Research*, 41(1): 1-20.
Özen, S., and Şahin, S. (2021) 'A Two-Population Mortality Model to Assess Longevity Basis Risk', *Risks*, 9(2): 44.
Pascariu, M. D., Basellini, U., Aburto, J. M., and Canudas-Romo, V. (2020) 'The Linear Link: Deriving Age-Specific Death Rates from Life Expectancy', *Risks*, *8*(4), 109.
Pascariu, M. D., Canudas-Romo, V., and Vaupel, J. W. (2018) 'The Double-Gap Life Expectancy Forecasting Model', *Insurance: Mathematics and Economics*, 78: 339-350.
Pascariu, M. D., Lenart, A., and Canudas-Romo, V. (2019) 'The Maximum Entropy Mortality Model: Forecasting Mortality using Statistical Moments', *Scandinavian Actuarial Journal*, 2019(4): 661–685.

Pavía, J. M., and Lledó, J. (2021) 'Estimation of the Combined Effects of Ageing and Seasonality on Mortality Risk: An Application to Spain', *Journal of the Royal Statistical Society: Series A (Statistics in Society)*, 185(2): 471–497.

Pavía, J. M., and Lledó, J. (2025) 'qlifetable: An R Package for Constructing Quarterly Life Tables', *PLOS One*, 20(2); DOI: 10.1371/journal.pone.0315937

Pearson-Stuttard, J., Caul, S., McDonald, S., Whamond, E., and Newtone, J. N. (2024) 'Excess Mortality in England Post COVID-19 Pandemic: Implications for Secondary Prevention', *The Lancet Regional Health – Europe*, 36: 100802; https://doi.org/10.1016/j.lanepe.2023.100802

Pedroza, C. (2006) 'A Bayesian Forecasting Model: Predicting US Male Mortality', *Biostatistics,* 7: 530–550.

Pelkiewicz, A.J., Ahmed, S.W., Fulcher, P., Johnson, K.L., Reynolds, S.M., Schneider, R.J., and Scott, A.J. (2019) 'A Review of the Risk Margin - Solvency II and Beyond', Report from the Risk Margin Working Party, Institute & Faculty of Actuaries, 9 September; https://www.actuaries.org.uk/system/files/field/document/Risk%20Margin%20Working%20Party%20Research%20Paper%20Final%2008082019.pdf

Perla, F., Richman, R., Scognamiglio, S., and Wüthrich, M. V. (2021) 'Time-series Forecasting of Mortality Rates using Deep Learning', *Scandinavian Actuarial Journal*, 2021(7): 572-598.

Perla, F., and Scognamiglio, S. (2023) 'Locally-Coherent Multi-Population Mortality Modelling via Neural Networks', *Decisions in Economics and Finance*, 46(1): 157-176.

Pichler, A., and Uhlig, D. (2023) 'Mortality in Germany during the COVID-19 Pandemic', *International Journal of Environmental Research and Public Health,* 20(20): 6942.

Pitacco, E. (2019) 'Heterogeneity in Mortality: A Survey with an Actuarial Focus', *European Actuarial Journal*, 9: 3–30.

Pitt, D., Li, J., and Lim T. K. (2018) 'Smoothing Poisson Common Factor Model for Projecting Mortality Jointly for Both Sexes', *ASTIN Bulletin*, 48 (2): 509-541.

Pittarello, G., Hiabu, M., and Villegas, A. M. (2025) 'Replicating and Extending Chain-Ladder via an Age–Period–Cohort Structure on the Claim Development in a Run-Off Triangle', *North American Actuarial Journal*; DOI: 10.1080/10920277.2025.2496725

Plat, R. (2009a) 'On Stochastic Mortality Modeling', *Insurance*: *Mathematics and Economics,* 45: 393-404.

Plat, R. (2009b) 'Stochastic Portfolio Specific Mortality and the Quantification of Mortality Basis Risk', *Insurance: Mathematics and Economics*, 45: 123-132.

Pollard, J.H. (1987) 'Projection of Age-specific Mortality rates', *Population Bulletin of the United Nations*, 21–22(21):55-69.

Poterba, J. M. (2001) 'Demographic Structure and Asset Returns', *Review of Economics and Statistics*, 83:565-584.

Prudential Regulation Authority (2018) 'Solvency II: Equity Release Mortgages', Consultation Paper CP13/18, July.

Qazvini, M. (2023) 'Survival Analysis of Longitudinal Data: The Case of the English Population Aged 50 and Over', *Journal of Demographic Economics,* 89(3): 419-463.

Qiao, C., and Sherris, M. (2013) 'Managing Systematic Mortality Risk with Group Self-Pooling and Annuitization Schemes', *Journal of Risk and Insurance,* 80: 949-974.

Qiao, Y., Wang, C.-W., and Zhu, W. (2024) 'Machine Learning in Long-term Mortality Forecasting', *Geneva Papers on Risk and Insurance - Issues and Practice*, 49:340-362.

Qiao, Y., Zhang, J., Zhu, W., Wang, C.-W. (2026) 'Quantile-based Interpretable Neural Network Models: Mortality Forecasting and Actuarial Simulations', *Insurance Mathematics and Economics*; DOI: 10.1016/j.insmatheco.2026.103235

Rabbi, A. M. F., and Mazzuco, S. (2021) 'Mortality Forecasting with the Lee-Carter Method: Adjusting for Smoothing and Lifespan Disparity', *European Journal of Population,* 37(1): 97-120.

Rachel, L., and Summers, L. H. (2019) 'On Falling Natural Real Rates, Fiscal Policy, and the Risk Of Secular Stagnation', *Brookings Papers on Economic Activity Conference Drafts,* March 7-8; https://www.brookings.edu/wp-content/uploads/2019/03/On-Falling-Neutral-Real-Rates-Fiscal-Policy-and-the-Risk-of-Secular-Stagnation.pdf

Raftery, A. E., Chunn, J. L., Gerland, P. and Ševčíková, H. (2013) 'Bayesian Probabilistic Projections of Life Expectancy for All Countries', *Demography*, 50(3): 777–801.

Raftery, A. E., Lalic, N., and Gerland, P. (2014) 'Joint Probabilistic Projection of Female and Male Life Expectancy'. *Demographic Research*, 30: 795–822.

Rakhmawan, S. A., Omar, M. H., Riaz, M., and Abbas, M. (2023) 'Hotelling T2 Control Chart for Detecting Changes in Mortality Models Based on Machine-Learning Decision Tree', *Mathematics*, 11(3): 566.

Ramsay, C. M., Oguledo, V. I., and Krutto, A. (2025) 'The Refinancing Enhanced Annuity Rider (REAR): A Novel Annuity Product Design and Its Contribution to Solving the Annuity Puzzle', *North American Actuarial Journal*; DOI: 10.1080/10920277.2025.2454454

Rau, R., Soroko, E., Jasilionis, D., and Vaupel, J. W. (2008) 'Continued Reductions in Mortality at Advanced Ages', *Population and Development Review*, 34(4):747-768.

Redzwan, N, and Ramli, R. (2022) 'A Bibliometric Analysis of Research on Stochastic Mortality Modelling and Forecasting', *Risks*, 10(10):191.

Renshaw, A., and Haberman, S. (2003a) 'Lee-Carter Mortality Forecasting: A Parallel Generalized Linear Modelling Approach for England and Wales Mortality Projections', *Journal of the Royal Statistical Society: Series C (Applied Statistics),* 52: 119–137.

Renshaw, A., and Haberman, S. (2003b) 'Lee-Carter Mortality Forecasting with Age-Specific Enhancement', *Insurance: Mathematics and Economics,* 33: 255–272.

Renshaw, A. E., and Haberman, S. (2003c) 'On the Forecasting of Mortality Reduction Factors', *Insurance: Mathematics and Economics*, 32: 379–401.

Renshaw, A. E., and Haberman, S. (2006) 'A Cohort-Based Extension to the Lee-Carter Model for Mortality Reduction Factors', *Insurance: Mathematics and Economics,* 38: 556–70.

Renshaw, A., and Haberman, S. (2008) 'On Simulation-Based Approaches to Risk Measurement in Mortality with Specific Reference to Poisson Lee-Carter Modelling', *Insurance: Mathematics and Economics,* 42: 797–816.

Richards, S. J. (2008) 'Detecting Year-of-Birth Mortality Patterns with Limited Data', *Journal of the Royal Statistical Society: Series A (Statistics in Society)*, 171(1):279-298.

Richards, S. J. (2009) 'Selected Issues in Modelling Mortality by Cause and in Small Populations', *British Actuarial Journal*, 15(Supplement 1):267–283.

Richards, S. (2021) 'A Value-at-Risk Approach to Mis-Estimation Risk', *British Actuarial Journal*, 26: e13.
Richards, S. J. (2024) 'Robust Mortality Forecasting in the Presence of Outliers', *British Actuarial Journal*; DOI: 10.1017/S1357321724000175
Richards, S. J., Currie, I. D., Kleinow, T., and Ritchie, G. P. (2019) 'A Stochastic Implementation of the APCI Model for Mortality Projections', *British Actuarial Journal*, 24:1–26.
Richards, S. J., Currie, I. D., Kleinow, T., and Ritchie, G. P. (2020) 'Longevity Trend Risk Over Limited Time Horizons', *Annals of Actuarial Science*, 14(2): 262–277.
Richards, S. J., Currie, I. D., and Ritchie, G. P. (2014) 'A Value-at-risk Framework for Longevity Trend Risk', *British Actuarial Journal*, 19(1): 116-167.
Richards, S. J., Kaufhold, K., and Rosenbusch, S. (2013) 'Creating Portfolio-Specific Mortality Tables: A Case Study', *European Actuarial Journal*, 3(2): 295-319.
Richman, R., and Wüthrich, M.V. (2021) 'A Neural Network Extension of the Lee–Carter Model to Multiple Populations', *Annals of Actuarial Science*, 15(2): 346-366.
Richter, A., and Weber, F. (2011) 'Mortality-Indexed Annuities: Managing Longevity Risk via Product Design', *North American Actuarial Journal,* 15: 212-236.
Risk, J., and Ludkovski, M. (2024) 'Expressive Mortality Models through Gaussian Process Kernels', *Astin Bulletin*, 54(2):1-33.
Rizzi, S., Kjærgaard, S., Bergeron Boucher, M.-P., Camarda, C. G., Lindahl-Jacobsen, R., and Vaupel, J.W. (2021) 'Killing Off Cohorts: Forecasting Mortality of Non-extinct Cohorts with the Penalized Composite Link Model', *International Journal of Forecasting*, 37 (1): 95-104.
Robben, J., and Antonio, K. (2024) 'Catastrophe Risk in a Stochastic Multi-population Mortality Model', *Journal of Risk and Insurance*; 10.1111/jori.12470
Robben, J., Antonio, K., and Devriendt, S. (2022) 'Assessing the Impact of the COVID-19 Shock on a Stochastic Multi-Population Mortality Model', *Risks*, 10(2): 26.
Robben, J., Antonio, K., and Kleinow, T. (2025) 'The Short-term Association between Environmental Variables and Mortality: Evidence from Europe', *Journal of the Royal Statistical Society Series A (Statistics in Society)*; DOI: 10.1093/jrsssa/qnaf052
Rogalla, R. (2021) 'Optimal Portfolio Choice in Retirement with Participating Life Annuities', *North American Actuarial Journal*, 25(S1): S182-S195.
Rong, X., Tao, C., and Zhao, H. (2023) 'Target Benefit Pension Plan with Longevity Risk and Intergenerational Equity', *ASTIN Bulletin*; http://10.1017/asb.2022.27
Roshani, A., Izadi, M., and Khaledi, B.-E. (2023) 'Bayesian Poisson Common Factor Model with Overdispersion for Mortality Forecasting in Multiple Populations', Communication in Statistics-Simulation and Computation; 10.1080/03610918.2023.2196381
Rostami, A., and Zadeh, A. H. (2024) 'A Markovian Aging Process Forecasting Model: Predicting US Mortality', *North American Actuarial Journal*; 10.1080/10920277.2024.2325343
Rubilar-Torrealba, R., Chahuán-Jiménez, K., de la Fuente-Mella, H., Elórtegui-Gómez, C. (2024) 'Bayesian Approach to Stochastic Estimation of Population Survival Curves in Chile Using ABC Techniques and Its Impact over Social Structures', *Computation*, 12(8):154.

Russo, V., Giacometti, R., Ortobelli, S., Rachev, S., and Fabozzi, F. (2011) 'Calibrating Affine Stochastic Mortality Models using Term Assurance Premiums', *Insurance: Mathematics and Economics,* 49: 53-60.

Russolillo, M., Giordano, G., and Haberman, S. (2011) 'Extending the Lee-Carter model: A Three-way Decomposition', *Scandinavian Actuarial Journal*, 2011 (2): 96–117.

Şahin, S., and Özen, S. (2024) 'A Quantitative Comparison of Mortality Models with Jumps: Pre- and Post-COVID Insights on Insurance Pricing', *Risks*, 12(3):53

Sakr, N. B. B., Loisel, S., Mansour, G., and Salhi, Y. (2026) 'Building a Life Table for Lebanon: Towards a Deeper Understanding of Our Future', *Risks*,14(2):34

Salhi, Y., and Thérond, P. E. (2018) 'Age-Specific Adjustment of Graduated Mortality', *ASTIN Bulletin*, 48, 543-569.

Santolino, M. (2020) 'The Lee-Carter Quantile Mortality Model', *Scandinavian Actuarial Journal*, 2020: 614–33.

Santolino, M. (2023) 'Should Selection of the Optimum Stochastic Mortality Model be Based on the Original or the Logarithmic Scale of the Mortality Rate?', Risks, 11(10):170

Schinzinger, E., Denuit, M. M., and Christiansen, M. C. (2016) 'A Multivariate Evolutionary Credibility Model for Mortality Improvement Rates', *Insurance: Mathematics and Economics*, 69: 70 – 81.

Schmeck, M. D., and Schmidli, H. (2021) 'Mortality Options: The Point of View of an Insurer', *Insurance: Mathematics and Economics*, 96(C): 98-115.

Schnürch, S., Kleinow, T., and Korn, R. (2021) 'Clustering-Based Extensions of the Common Age Effect Multi-Population Mortality Model', *Risks*, *9*(3), 45.

Schnürch, S., Kleinow, T., Korn, R., and Wagner, A. (2022) 'The Impact of Mortality Shocks on Modelling and Insurance Valuation as Exemplified by Covid-19', *Annals of Actuarial Science*, 16(3): 498-526.

Schnürch, S., Kleinow, T., and Wagner, A. (2023) 'Accounting for Covid-19-Type Shocks in Mortality Modeling: A Comparative Study', *Journal of Demographic Economics*, 89(3): 483-512.

Schnürch, S., and Korn, R. (2022) 'Point and Interval Forecasts of Death Rates using Neural Networks', *ASTIN Bulletin*, 52(1): 333-360.

Schrager, D. F. (2006) 'Affine Stochastic Mortality', *Insurance: Mathematics and Economics*, 38: 81–97.

Scognamiglio, S. (2022a) 'Calibrating the Lee-Carter and the Poisson Lee-Carter Models via Neural Networks', *ASTIN Bulletin*, 52(2): 519-561.

Scognamiglio, S. (2022b) 'Longevity Risk Analysis: Applications to the Italian Regional Data', *Quantitative Finance and Economics*, 6(1): 138-157.

Scognamiglio, S., and Marino, M. (2023) 'Backtesting Stochastic Mortality Models by Prediction Interval-based Metrics', *Quality & Quantity,* 57(4), 3825-3847.

Scott, A. J. (2024) *The Longevity Imperative: Building a Better Society for Healthier, Longer Lives*, Oxford: Blackwell.

Sevčíková, H., and Raftery, A. E. (2021) 'Probabilistic Projection of Sub-National Life Expectancy', *Journal of Official Statistics*, 37(3): 591-610.

Shang, H. L. (2012) 'Point and Interval Forecasts of Age-Specific Life Expectancies: A Model Averaging Approach', *Demographic Research*, 27 (21): 593-644.

Shang, H. L. (2016) 'Mortality and Life Expectancy Forecasting for a Group of Populations in Developed Countries: A Multilevel Functional Data Method', *Annals of Applied Statistics*, 10(3): 1639-1672.

Shang, H. L. (2019) 'Dynamic Principal Component Regression: Application to Age-Specific Mortality Forecasting', *ASTIN Bulletin*, 49 (3): 619-645.

Shang, H. L. (2024) 'Change-point Detection in Functional Time Series: Applications to Age-specific Mortality and Fertility', *Annals of Operations Research*; DOI: 10.1007/s10479-024-06391-w.

Shang, H. L., and Haberman, S. (2018) 'Model Confidence Sets and Forecast Combination: An Application to Age-Specific Mortality', *Genus*, 74, 19.

Shang, H. L., and Haberman, S. (2020a) 'Retiree Mortality Forecasting: A Partial Age-Range or a Full Age-Range Model?', *Risks*, *8(*3): 69.

Shang, H. L., and Haberman, S. (2020b) 'Forecasting Multiple Functional Time Series in a Group Structure: An Application to Mortality', *Astin Bulletin*, 50(2): 357-379.

Shang, H. L., and Haberman, S. (2024) 'Forecasting Age Distribution of Life-table Death Counts via α-transformation', *Scandinavian Actuarial Journal*; 10.1080/03461238.2024.2425723

Shang, H. L., and Haberman, S. (2025) 'Constructing Prediction Intervals for the Age Distribution of Deaths', *Scandinavian Actuarial Journal*, DOI: 10.1080/03461238.2025.2544265

Shang, H. L., Haberman, S., and Xu, R. (2022) 'Multi-Population Modelling and Forecasting Life-table Death Counts', *Insurance: Mathematics and Economics*, 106: 239-253.

Shang, H. L., and Hyndman, R. (2017) 'Grouped Functional Time Series Forecasting: An Application to Age-Specific Mortality Rates', *Journal of Computational and Graphical Statistics*, 26(2): 330-343.

Shang, Z., Goovaerts, M., and Dhaene, J. (2011) 'A Recursive Approach to Mortality-linked Derivative Pricing', *Insurance: Mathematics and Economics,* 49: 240-248.

Shao, A. W., Hanewald, K., and Sherris, M. (2015) 'Reverse Mortgage Pricing and Risk Analysis allowing for Idiosyncratic House Price Risk and Longevity Risk', *Insurance: Mathematics and Economics*, 63: 76–90.

Shapovalov, V., Landsman, Z., and Makov, U. (2021) 'Exchangeable Mortality Projection', *European Actuarial Journal*, 11(1): 113-133.

Sharma, N., Selvamuthu, D., and Natarajan, S. (2022) 'Variable Annuities Valuation under a Mixed Fractional Brownian Motion Environment with Jumps Considering Mortality Risk', *Applied Stochastic Models in Business and Industry,* 38(6): 1019-1038.

Shen Y., Sherris, M., Wang, Y., and Ziveyi, J. (2025) 'Optimal Hedging of Longevity Risks for Group Self-annuity Portfolios', *Journal of Risk & Insurance*, 92(4); DOI: 10.1111/jori.70024

Shen Y., and Siu T. K. (2013) 'Longevity Bond Pricing under Stochastic Interest Rate and Mortality with Regime Switching', *Insurance: Mathematics and Economics,* 52: 114-123.

Shen Y., Yang, X., Liu, H., and Li, Z. (2024) 'Advancing Mortality Rate Prediction in European Population Clusters: Integrating Deep Learning and Multiscale Analysis', *Scientific Reports*, 14(1); 10.1038/s41598-024-56390-x

Sherris, M., Xu, Y. and Ziveyi, J. (2020) 'Cohort and Value-Based Multi-Country Longevity Risk Management', *Scandinavian Actuarial Journal,* 2020 (7): 650-676.

Shi J., Shi Y., Wang P., Zhu W. D. (2023) 'Multi-population Mortality Modelling: A Bayesian Hierarchical Approach', *ASTIN Bulletin*; 10.1017/asb.2023.29

Shi, Y., Tang, S., and Li, J. (2020) 'A Two-Population Extension of the Exponential Smoothing State Space Model with a Smoothing Penalisation Scheme', *Risks*, *8*(3): 67.

Shimizu, Y., Minami, Y., and Ito, R. (2021) 'Why Does a Human Die? A Structural Approach to Cohort-Wise Mortality Prediction Under Survival Energy Hypothesis', *ASTIN Bulletin*, 51(1): 191-219.

Shimizu, Y., Shirai, K., Kojima, Y., Mitsuda, D., and Inoue, M. (2023) 'Survival Energy Models for Mortality Prediction and Future Prospects', *ASTIN Bulletin*, 53(2): 377-391.

Shull, M. L., Richardson, R., Groendyke, C., and Hartman, B. (2025) 'A Multivariate Spatiotemporal Model for County-level Mortality Data in the Contiguous United States', *Annals of Actuarial Science*; DOI: 10.1017/S1748499525000016

Sifre-Armengol, C., Pavía, J. M., and Benito, J. L. (2025) 'A Comprehensive Database of Estimates and Forecasts of Spanish Sex–age Death Rates by Climate Area, Income Level, and Habitat Size (2010–2050)', *Demographic Research*, 52:1-24

Siu, J., and Liu, Y. (2021) 'Recent Declines in Life Expectancy: Implication on Longevity Risk Hedging', *Insurance: Mathematics and Economics*, 99: 376-394.

Sliwka, P., and Socha, L. (2022) 'Application of Continuous Non-Gaussian Mortality Models with Markov Switchings to Forecast Mortality Rates', *Applied Sciences*, 12: 6203.

So, K. R., Cruz, S. C., Marcella, A., Briones, J., and Garces, L. P. D. (2025) 'Uncertainty in Pricing and Risk Measurement of Survivor Contracts', *Risks*, 13(2):35

Spreeuw, J., Owadally, I., and Kashif, M. (2022) 'Projecting Mortality Rates Using a Markov Chain'**,** *Mathematics*, *10*(7): 1162.

SriDaran, D., Sherris, M., Villegas, A., and Ziveyi, J. (2022) 'A Group Regularisation Approach for Constructing Generalised Age-Period-Cohort Mortality Projection Models', *ASTIN Bulletin*, 52(1): 247-289.

Stefanucci, M., and Mazzuco, S. (2022) 'Analysing Cause-specific Mortality Trends using Compositional Functional Data Analysis', *Journal of the Royal Statistical Society Series A: Statistics in Society*, 185(1): 61–83.

Stevens, R., De Waegenaere, A., and Melenberg, B. (2010), 'Longevity Risk in Pension Annuities with Exchange Options: The Effect of Product Design', *Insurance: Mathematics and Economics,* 46: 222-234.

Strozza, C., Bergeron-Boucher, M.-P., Callaway, J., and Drefahl, S. (2024) 'Forecasting Inequalities in Survival to Retirement Age by Socioeconomic Status in Denmark and Sweden', *European Journal of Population*, 40(1); 10.1007/s10680-024-09704-8

Strozza, C., Vigezzi, S., Callaway, J., Aleksandrovs, A., Kashnitsky, I. (2025) 'Socioeconomic Inequalities in Survival to Retirement Age in Denmark: A Register-Based Analysis', *Genus*, 81(1); DOI: 10.1186/s41118-025-00258-z

Su, K. C., and Yue, J. C. (2021) 'A Synthesis Mortality Model for the Elderly', *North American Actuarial Journal,* 25(S1): S457-S481.

Summers, L. H. (2013) Speech at the IMF Fourteenth Annual Research Conference in Honor of Stanley Fischer, Washington D.C.

Summers, L. H. (2014) 'US Economic Prospects: Secular Stagnation, Hysteresis, and the Zero Lower Bound', *Business Economics*, 49(2): 65-73.

Sweeting, P. J. (2011) 'A Trend-Change Extension of the Cairns-Blake-Dowd Model', *Annals of Actuarial Science,* 5: 143–162.

Szentkereszti, G., and Vékás, P. (2026) 'Mortality Forecasting in Geographical Space and Time', *Astin Bulletin*; DOI: 10.1017/asb.2026.10092

Tan, C. I., Li, J., Li, J. S.-H., and Balasooriya, U. (2014) 'Parametric Mortality Indexes: From Index Construction to Hedging Strategies', *Insurance: Mathematics and Economics,* 59, 285–299.

Tan, K. S., Weng, C., and Zhang, J. (2022) Optimal Dynamic Longevity Hedge with Basis Risk' *European Journal of Operational Research*, 297(1): 325-337.

Tang, S., and Li, J. (2021) 'Market Pricing of Longevity-linked Securities', *Scandinavian Actuarial Journal*, 2021(5): 408-436.

Tang, S., Li, J., and Tickle, L. (2022) **'**A New Fourier Approach under the Lee-Carter Model for Incorporating Time-Varying Age Patterns of Structural Changes', *Risks*, *10*(8): 147.

Tang, S., Li, J., and Tickle, L. (2023) 'A Hermite Spline Approach for Modelling Population Mortality', *Annals of Actuarial Science*, 17(2): 243-284.

Tang, S., Li, J., and Tickle, L. (2025) 'Forecasting Mortality Rates using Population Composition Data', *Journal of Population Research*,42(4); DOI: 10.1007/s12546-025-09407-9

Thatcher, A. R., Kannisto, V., and Vaupel, J. W. (1998) *The Force of Mortality at Ages 80 to 120*, Odense, Denmark: Odense University Press.

Thwaites, G. (2015) 'Why are Real Interest Rates so Low? Secular Stagnation and the Relative Price of Investment Goods', Bank of England Staff Working Paper No 564; https://www.bankofengland.co.uk/working-paper/2015/why-are-real-interest-rates-so-low-secular-stagnation-and-the-relative-price-of-investment-goods

Tomas, J., and Planchet, F. (2015) 'Prospective Mortality Tables: Taking Heterogeneity into Account', *Insurance: Mathematics and Economics*, 63: 169–190.

Torri, T. and Vaupel, J. W. (2012) 'Forecasting Life Expectancy in an International Context', *International Journal of Forecasting*, 28(2): 519–531.

Tsai, C. C.-L., and Cheng, E. S. (2021) 'Incorporating Statistical Clustering Methods into Mortality Models to Improve Forecasting Performances', *Insurance: Mathematics and Economics*, 99(C): 42-62.

Tsai, C. C.-L., and Liang, X. (2018) 'Application of Relational Models in Mortality Immunization', *North American Actuarial Journal*, 22(4): 509-532.

Tsai, C. C.-L., and Lin, T. (2017a) 'A Bühlmann Credibility Approach to Modeling Mortality Rates', *North American Actuarial Journal,* 21(2): 204-227.

Tsai, C. C.-L., and Lin, T. (2017b) 'Incorporating the Bühlmann Credibility into Mortality Models to Improve Forecasting Performances', *Scandinavian Actuarial Journal*, 2017: 419-440..ca

Tsai, J., Wang, J., and Tzeng, L. (2010) 'On the Optimal Product Mix in Life Insurance Companies using Conditional Value at Risk', *Insurance: Mathematics and Economics,* 46: 235-241.

Tzeng, L. Y., Wang, J. L., and Tsai, J. T. (2011) 'Hedging Longevity Risk when Interest Rates are Uncertain', *North American Actuarial Journal,* 15: 201-211.

Ungolo, F., Garces, L. P. D. M., Sherris, M., and Zhou, Y. (2023) 'Estimation, Comparison, and Projection of Multifactor Age–Cohort Affine Mortality Models', *North American Actuarial Journal*; 10.1080/10920277.2023.2238793

Ungolo, F., Garces, L. P. D. M., Sherris, M., and Zhou, Y. (2024) 'Affine Mortality : An R Package for Estimation, Analysis, and Projection of Affine Mortality Models', *Annals of Actuarial Science*; 10.1017/S1748499524000149

United Nations (2007). *World Population Prospects: The 2006 Revision,* New York: United Nations.

van Berkum, F., Antonio, K., and Vellekoop, M. H. (2016) 'The Impact of Multiple Structural Changes on Mortality Predictions', *Scandinavian Actuarial Journal*, 2016(7): 581-603.

van Berkum, F., Antonio, K., and Vellekoop, M. H. (2017) 'A Bayesian Joint Model for Population and Portfolio-Specific Mortality', *ASTIN Bulletin*, 47(3): 681-713.

van Berkum, F., Antonio, K., and Vellekoop, M. H. (2021) 'Quantifying Longevity Gaps Using Micro-level Lifetime Data', *Journal of the Royal Statistical Society: Series A (Statistics in Society)*, 184(2): 548-570.

van Berkum, F., Melenberg, B., and Vellekoop, M. H. (2025) 'Estimating the Impact of COVID-19 on Mortality using Granular Data', *Insurance Mathematics and Economics,* 121(C): 144-156.

Varga, L. (2025) 'Forecasting Cause-of-death Mortality with Single- and Multi-population Models in Hungary', *Scandinavian Actuarial Journal*; DOI: 10.1080/03461238.2025.2480846

Vaupel, J. W., and Canudas-Romo, V. (2003) 'Decomposing Change in Life Expectancy: A Bouquet of Formulas in Honor of Nathan Keyfitz's 90th Birthday', *Demography*, 40(2): 201–216.

Venter, G., and Şahın, S. (2018) 'Parsimonious Parameterization of Age-Period-Cohort Models by Bayesian Shrinkage', *ASTIN Bulletin*, 48(1):1-22.

Venter, G., and Şahin, Ş. (2022) 'Semiparametric Regression for Dual Population Mortality', *North American Actuarial Journal*, 26(3): 403-427.

Villegas, A. M., Bajekal, M., and Haberman, S. (2023) 'On the Decomposition of Mortality Models into Causes of Death', Society of Actuaries Research Institute, Schaumburg, Illinois 60173; https://www.soa.org/4ae33f/globalassets/assets/files/resources/essays-monographs/2023-living-to-100-compendium/2023-living-to-100-comp-villegas.pdf

Villegas, A. M., Bajekal, M., and Haberman, S. (2025) 'Modelling Mortality by Cause of Death and Socio-economic Stratification: An Analysis of Mortality Differentials in England', *Decisions in Economics and Finance*, 48: 1219-1257.

Villegas, A. M., Bajekal, M., Haberman, S., and Zhou, L. (2024) 'Key Drivers of Long-Term Rates of Mortality Improvements in the United States: Period, Cohort, and Cause of Death Analysis, 1959–2016', *North American Actuarial Journal*, 28(1), 187–217.

Villegas, A. M., and Haberman, S. (2014) 'On the Modelling and Forecasting of Socio-Economic Mortality Differentials: An Application to Deprivation and Mortality in England', *North American Actuarial Journal*, 18(1): 168-193.

Villegas, A. M., Haberman, S., Kaishev, V. K., and Millossovich, P. (2017) 'A Comparative Study of Two-Population Models for the Assessment of Basis Risk in Longevity Hedges', *ASTIN Bulletin*, 47(3): 631-679.

Villegas, A. M., Kaishev, V. K., and Millossovich (2018) 'StMoMo: An R Package for Stochastic Mortality Modeling', *Journal of Statistical Software*, 84: 1–38.

Vlieghe, G. (2022) 'Demographics and Other Constraints on Future Monetary policy', *Journal of the Economics of Ageing*, 23, 100424.

Wan, C., and Bertschi, L. (2015) 'Swiss Coherent Mortality Model as a Basis for Developing Longevity De-Risking Solutions for Swiss Pension Funds: A Practical Approach', *Insurance: Mathematics and Economics*, 63: 66–75.

Wang, C.-W., Huang, H.-C., and Liu, I.-C. (2011a) 'A Quantitative Comparison of the Lee-Carter Model under Different Types of Non-Gaussian Innovations', *Geneva Papers on Risk and Insurance – Issues and Practice,* 36: 675-696.

Wang, C.-W., Huang, H.-C., and Liu, I.-C. (2013) 'Mortality Modeling with Non-Gaussian Innovations and Applications to the Valuation of Longevity Swaps', *Journal of Risk and Insurance*, 80: 775-798.

Wang, C.-W., and Yang, S. (2013) 'Pricing Survivor Derivatives with Cohort Mortality Dependence under the Lee–Carter Framework', *Journal of Risk and Insurance*, 80: 1027–1056.

Wang, C.-W., Yang, S., and Huang H.-C. (2015) 'Modeling Multi-Country Mortality Dependence and its Application in Pricing Survivor Index Swaps – A Dynamic Copula Approach', *Insurance: Mathematics and Economics*, 63: 30–39.

Wang, C., Zhang, J., and Zhu, W. (2021a) 'Neighbouring Prediction for Mortality', *ASTIN Bulletin*, 51(3), 689-718.

Wang, D., and Chan, W.-S. (2022) 'Backcasting Mortality in England and Wales, 1600–1840', *North American Actuarial Journal*, 26(1): 102-122.

Wang, H., and Preston, S. H. (2009) 'Forecasting United States Mortality using Cohort Smoking Histories', *Proceedings of the National Academy of Sciences of the United States of America* 106: 393–8.

Wang, H.-C., Yue, C.-S. J., Chang, T.-C., and Chang, T.-C. (2023a) 'Morbidity Compression and Cancer Insurance', *Journal of Demographic Economics*, 89(3): 465-482.

Wang, H.-C., Yue, C.-S. J., and Chong, C.-T. (2018) 'Mortality Models and Longevity Risk for Small Populations', *Insurance: Mathematics and Economics*, 78: 351-359.

Wang, J., Wen, L., Xiao, L., and Wang, C. (2023b) 'Time-series Forecasting of Mortality Rates using Transformer, *Scandinavian Actuarial Journal*; 10.1080/03461238.2023.2218859

Wang, J. L., Hsieh, M., and Chiu, Y. (2011b) 'Using Reverse Mortgages to Hedge Longevity and Financial Risks for Life Insurers: A Generalized Immunization Approach', *Geneva Papers on Risk and Insurance – Issues and Practice,* 36: 697-717.

Wang, J.L., Huang, H.-C., Yang, S.S., and Tsai, J.T. (2010) 'An Optimal Product Mix for Hedging Longevity Risk in Life Insurance Companies: The Immunization Theory Approach', *Journal of Risk and Insurance*, 77: 473-497.

Wang, L., Chiu, M. C., and Wong, H. Y. (2021b) 'Volterra Mortality Model: Actuarial Valuation and Risk Management with Long-range Dependence', *Insurance: Mathematics and Economics*, 96(C): 1-14.

Wang, L., Valdez, E., and Piggott, J. (2008) 'Securitization of Longevity Risk in Reverse Mortgages', *North American Actuarial Journal,* 12: 345-371.
Wang, P., Pantelous, A. A., and Vahid, F. (2023c) 'Multi-Population Mortality Projection: The Augmented Common Factor Model with Structural Breaks', *International Journal of Forecasting*, 39(1): 450-469.
Wang, S., Shang. H., Tickle, L., and Li, H. (2024) 'Forecasting Age- and Sex-Specific Survival Functions: Application to Annuity Pricing', *Risks*, 12(7):117
Wang, Z., and Li, J. S.-H. (2016) 'A DCC-GARCH Multi-population Mortality Model and its Applications to Pricing Catastrophic Mortality Bonds', *Finance Research Letters*, 16(C): 103-111. Weinert, J. H., and Gründl, H. (2021) 'The Modern Tontine', *European Actuarial Journal*, 11: 49–86.
Wen, J., Cairns, A.J.G., and Kleinow, T. (2021) 'Fitting Multi-Population Mortality Models to Socio-Economic Groups', *Annals of Actuarial Science*, 15: 144-172.
Wen, J., Kleinow, T., and Cairns, A.J.G. (2020) 'Trends in Canadian Mortality by Pension Level: Evidence from the CPP and QPP', *North American Actuarial Journal*, 24: 533-561.
Wen, J., Cairns, A.J.G., and Kleinow, T. (2023) 'Modelling Socio-economic Mortality at Neighbourhood Level', *ASTIN Bulletin*, 53(2): 285–310.
Wills, S., and Sherris, M. (2010) 'Securitization, Structuring and Pricing of Longevity Risk', *Insurance: Mathematics and Economics,* 46: 173-185.
Wilmoth, J. R. (1995) 'Are Mortality Projections always more Pessimistic when Disaggregated by Cause of Death?', *Mathematical Population Studies*, 5(4):293–319.
Wilmoth, J. R. (2000) 'Demography of Longevity: Past, Present, and Future Trends', *Experimental Gerontology*, 35(9-10):1111–1129.
Wilmoth, J. R. and Horiuchi, S. (1999) 'Rectangularization Revisited: Variability of Age at Death within Human Populations', Demography, 36(4): 475–495.
Wilmoth, J. R., Zureick, S., Canudas-Romo, V., Inoue, M., and Sawyer, C. (2012) 'A Flexible Two Dimensional Mortality Model for Use in Indirect Estimation', *Population Studies*, 66(1): 1–28.
Wong, J. S. T., Forster, J. J., and Smith, P. W. F. (2018) 'Bayesian Mortality Forecasting with Overdispersion', *Insurance: Mathematics and Economics,* 83:206-221.
Wong, J. S. T., Forster, J. J., and Smith, P. W. F. (2023) 'Bayesian Model Comparison for Mortality Forecasting', *Journal of the Royal Statistical Society Series C Applied Statistics*; DOI: 10.1093/jrsssc/qlad021
Wong, K., Li, J., and Tang, S. (2020) 'A Modified Common Factor Model for Modelling Mortality Jointly for Both Sexes', *Journal of Population Research*, 37: 181–212.
Wong, T., Chiu, M., Wong, H. (2017) 'Managing Mortality Risk with Longevity Bonds when Mortality Rates are Cointegrated', *Journal of Risk and Insurance*, 84(3): 987-1023.
Wu, Y., Chen, A., Xu, Y., Pan, G., and Zhu, W. (2024) 'Modeling Mortality with Kernel Principal Component Analysis (KPCA) Method', *Annals of Actuarial Science*; DOI: 10.1017/S1748499524000277
Xiao, H., Zhao, M., Li, X, and Bai, A. (2023) 'An Innovation Mortality Prediction Model with Cohort Effect', *Communications in Statistics-Theory and Methods*;10.1080/03610926.2023.2264998

Xie, S., and Shang, Q. (2024) 'Pricing the Extreme Mortality Bonds Based on the Double Exponential Jump Diffusion Model', *Journal of Finance Research*, 8(1):24

Xu. J. Chen, X., and Yang, Y. (2024) 'Pricing Longevity Bond with Affine-jump-diffusion Multi-cohort Mortality Model, *Journal of Computational and Applied Mathematics*; 10.1016/j.cam.2024.115800

Xu, Y., Sherris, M., and Ziveyi, J. (2020) 'Market Price of Longevity Risk for a Multi-Cohort Mortality Model with Application to Longevity Bond Option Pricing', *Journal of Risk and Insurance*, 87(3): 571-595.

Yan, H., Peters, G., and Chan, J. (2021) 'Mortality Models Incorporating Long Memory for Life Table Estimation: A Comprehensive Analysis', *Annals of Actuarial Science*, 15(3): 567-604.

Yang, B., Li, J., and Balasooriya, U. (2015) 'Using Bootstrapping to Incorporate Model Error for Risk-Neutral Pricing of Longevity Risk', *Insurance: Mathematics and Economics,* 62, 16–27.

Yang, B., Li, J., and Balasooriya, U. (2016) 'Cohort Extensions of the Poisson Common Factor Model for Modelling Both Genders Jointly', *Scandinavian Actuarial Journal*, 2016(2), 93-112.

Yang, S., and Zhou, K. Q. (2023) 'On Risk Management of Mortality and Longevity Capital Requirement: A Predictive Simulation Approach', *Risks*, 11(12):206.

Yang, S. S. (2011) 'Securitization and Tranching Longevity and House Price Risk for Reverse Mortgage Products', *Geneva Papers on Risk and Insurance – Issues and Practice,* 36: 648-674.

Yang, S. S., Huang, H.-C., and Yeh, Y.-Y. (2019) 'Optimal Longevity Hedging Framework for Insurance Companies Considering Basis and Mispricing Risks', *Journal of Risk and Insurance*, 86 (3): 783-805.

Yang, S. S., and Wang, C.-W. (2013) 'Pricing and Securitization of Multi-Country Longevity Risk with Mortality Dependence', *Insurance: Mathematics and Economics,* 52: 157-169.

Yang, S. S., Yeh, Y.-Y., Yue, J. C., and Huang, H.-C. (2021) 'Understanding Patterns of Mortality Homogeneity and Heterogeneity across Countries and Their Role in Modelling Mortality Dynamics and Hedging Longevity Risk', *North American Actuarial Journal*, 25(S1): S132-S155.

Yang, S. S., Yue, J., and Huang, H.-C. (2010) 'Modeling Longevity Risks using a Principal Component Approach: A Comparison with Existing Stochastic Mortality Models', *Insurance: Mathematics and Economics,* 46: 254-270.

Yang, S. S., Yueh, M.-L., and Tang, C.-H. (2008) 'Valuation of the Interest Rate Guarantee Embedded in Defined Contribution Pension Plans', *Insurance: Mathematics and Economics,* 42: 920-934.

Yang, Y., Chen, S., Cui, Z., and Zhang, Z. (2024) 'Valuation of Guaranteed Lifelong Withdrawal Benefit with the Long-term Care Option', *Insurance: Mathematics and Economics,* 119(C): 179-193.

Yue, J. C., and Huang, H.-C. (2011) 'A Study of Incidence Experience for Taiwan Life Insurance', *Geneva Papers on Risk and Insurance – Issues and Practice,* 36: 718-733.

Yue, J. C., Tu, M.-H., and Leong, Y.-Y. (2024a) 'A Spatial Analysis of Health and Longevity of Taiwan People', *Geneva Papers on Risk and Insurance-Issues and Practice*, 49(2): 384-399.

Yue, J. C., Wang, H.-C., Leong, Y.Y., and Su W.-P. (2018) 'Using Taiwan National Health Insurance Database to Model Cancer Incidence And Mortality Rates', *Insurance: Mathematics and Economics*, 78: 316-324.

Yue, J. C., Wang, H.-C., and Liou, Y. (2024b) 'Using the Taiwan National Health Insurance Database to Explore the Need for Long-term Care', *Geneva Papers on Risk and Insurance-Issues and Practice*, 49(2): 400-416.

Yue, J. C., Wang, T-Y., and Wang, H.-C. (2021) 'Using Graduation to Modify the Estimation of Lee-Carter Model for Small Populations', *North American Actuarial Journal*, 25(S1): S410-S420.

Zeddouk, F., and Devolder, P. (2020a) 'Longevity Modelling and Pricing under a Dependent Multi-Cohort Framework', *Risks*, 8: 121.

Zeddouk, F., and Devolder, P. (2020b) 'Mean Reversion in Stochastic Mortality: Why and How?', *European Actuarial Journal*, 10(2): 499–525.

Zeddouk, F., and Devolder, P. (2023) 'Pricing and Hedging of Longevity Basis Risk through Securitisation', *ASTIN Bulletin*; 10.1017/asb.2023.37

Zelenko, I. (2014) 'Longevity Risk and the Stability of Retirement Systems: The Chilean Longevity Bond Case', *Journal of Alternative Investments,* 17 (1): 35–54.

Zhang, L., and Zhuang, Y. (2025) 'What KAN Mortality Say: Smooth and Interpretable Mortality Modeling using Kolmogorov−Arnold Networks, *Astin Bulletin*; DOI: 10.1017/asb.2025.10079

Zhang, X., Huang, F., Hui, F.K.C., and Haberman, S. (2023) 'Cause-of-Death Mortality Forecasting Using Adaptive Penalized Tensor Decompositions', *Insurance: Mathematics and Economics*, 111: 193-213.

Zhang, X., Li, Y., and Guo, J. (2024) 'The Role of Longevity-Indexed Bond in Risk Management of Aggregated Defined Benefit Pension Scheme', *Risks*, 12(3):49.

Zheng, H., Wang, H., Zhu, R., and Xue, J.-H. (2025) 'Fine-grained Mortality Forecasting with Deep Learning', *Annals of Actuarial Science*; DOI: 10.1017/S1748499525100171

Zhou, H., Zhou, K. Q., and Li, X. (2022) 'Stochastic Mortality Dynamics Driven by Mixed Fractional Brownian Motion', *Insurance: Mathematics and Economics*, 106(C): 218-238.

Zhou, K. Q., and Li, J. S.-H. (2017) 'Dynamic Longevity Hedging in the Presence of Population Basis Risk: A Feasibility Analysis from Technical and Economic Perspectives', *Journal of Risk and Insurance*, 84(S1): 417-437.

Zhou. K. Q., and Li, J. S.-H. (2019) 'Delta-Hedging Longevity Risk under the M7–M5 Model: The Impact of Cohort Effect Uncertainty and Population Basis Risk, *Insurance: Mathematics and Economics,* 84:1-21.

Zhou, K. Q., and Li, J. S.-H. (2020) 'Asymmetry in Mortality Volatility and its Implications on Index-based Longevity Hedging', *Annals of Actuarial Science*, 14(2): 278–301.

Zhou, K. Q., and Li, J. S.-H. (2021) 'Longevity Greeks: What do Insurers and Capital Market Investors Need to Know?', *North American Actuarial Journal*, 25(S1): S66-S96.

Zhou, K. Q., and Li, J. S.-H. (2023) 'The Impact of Long Memory in Mortality Differentials on Index-based Longevity Hedges', *Journal of Demographic Economics*, 89(3):533-552.

Zhou, K. Q., Li, J. S.-H., and Lyu, P. (2024) 'Bringing Parametric Mortality Indexes to Practice: A Generalized CBD Model with Stochastic Socioeconomic Differentials in Mortality Improvements', *Geneva Papers on Risk and Insurance - Issues and Practice*, 49(2): 295-319.

Zhou, K. Q., and Zhu, X. (2025) 'A Bayesian Generalized Additive Model Approach for Forecasting Mortality Improvement with External Information', *Journal of the Royal Statistical Society Series A (Statistics in Society)*, 189(2): 973-997.

Zhou, R. (2019) 'Modelling Mortality Dependence with Regime-Switching Copulas', *ASTIN Bulletin*, 49 (2): 373-407.

Zhou, R., and Ji, M. (2021) 'Modelling Mortality Dependence: An Application of the Dynamic Vine Copula', *Insurance: Mathematics and Economics*, 99(C): 241-255.

Zhou, R., and Li, J. S.-H. (2013) 'A Cautionary Note on Pricing Longevity Index Swaps', *Scandinavian Actuarial Journal*, 2013(1): 1-23.

Zhou, R., and Li, J. S.-H. (2022) 'A Multi-parameter-level Model for Simulating Future Mortality Scenarios with COVID-alike Effects, *Annals of Actuarial Science*, 16(3): 453-477.

Zhou, R., Li, J. S.-H., and Tan, K. S. (2011) 'Economic Pricing of Mortality-Linked Securities in the Presence of Population Basis Risk', *Geneva Papers on Risk and Insurance – Issues and Practice,* 36: 544-566.

Zhou, R., Li, J. S.-H., and Tan, K. S. (2013) 'Pricing Standardized Mortality Securitizations: A Two-Population Model with Transitory Jump Effects', *Journal of Risk and Insurance*, 80: 733-774.

Zhou, R., Li, J. S.-H., and Tan, K. S. (2015) 'Modeling Longevity Risk Transfers as Nash Bargaining Problems: Methodology and insights', *Economic Modelling*, 51:460-472.

Zhou, R., Li, J. S.-H., and Zhou, K. Q. (2024) 'The Impact of Longevity Annuity Provision on Retirement Income Planning for Canadians—A Modified General Endogenous Grid Method', *North American Actuarial Journal*; DOI: 10.1080/10920277.2024.2417722

Zhou, R., Wang, Y., Kaufhold, K., Li, J. S.-H., and Tan, K. S. (2014) 'Modeling Period Effects in Multi-Population Mortality Models: Applications to Solvency II', *North American Actuarial Journal*, 18(1): 150-167.

Zhao, Y., Costabile, M., Massabó, I., Russo, E., Staino, A., and Mamon, R. (2026) 'Pricing a Guaranteed Annuity Option under a Stochastic Correlation Setting', *Stochastic Analysis and Applications*, 1–23; https://doi.org/10.1080/07362994.2026.2616052

Zhou, Y., Garces, L. P., Yang, S., Sherris, M., and Ziveyi, J. (2025) 'Risk-sharing Rules for Mortality Pooling Products with Stochastic and Correlated Mortality Rates', *Astin Bulletin*, DOI: 10.1017/asb.2025.10064

Zhou, Y., Sherris, M., Ziveyi, J., and Xu, M. (2022) 'An Innovative Design of Flexible, Bequest-enhanced Life Annuity with Natural Hedging', *Scandinavian Actuarial Journal*, 2022(6):1-22.

Zhu, N., and Bauer, D. (2011) 'Applications of Forward Mortality Factor Models in Life Insurance Practice', *Geneva Papers on Risk and Insurance – Issues and Practice,* 36: 567-594.

Zhu, N., and Bauer, D. (2013) 'Coherent Pricing of Life Settlements under Asymmetric Information', *Journal of Risk and Insurance*, 80: 827-851.

Zhu, N., and Bauer, D. (2014) 'A Cautionary Note on Natural Hedging of Longevity Risk', *North American Actuarial Journal*, 18(1): 104-115.

Zhu, N., and Bauer, D. (2022) 'Modeling the Risk in Mortality Projections', *Operations Research*, 70(4):2069-2084.

Zhu, W., Tan, K. S., and Wang, C.-W. (2017) 'Modeling Multicountry Longevity Risk With Mortality Dependence: A Lévy Subordinated Hierarchical Archimedean Copulas Approach', *Journal of Risk and Insurance*, 84(S1): 477-493.

Zhu, X., and Zhou, K.Q. (2023) 'Smooth Projection of Mortality Improvement Rates: A Bayesian Two-Dimensional Spline Approach', *European Actuarial Journal*, 13: 277–305.

Zhu, X., Zhou, K.Q., and Wang, Z. (2025) 'Mortality Modeling via Vitality: Model Constructions and Actuarial Applications', *Insurance: Mathematics and Economics*; DOI: 10.1016/j.insmatheco.2025.103181

Zuo, W., Damle, A., Tuljapurkar, S. (2025) 'Sensitivity and Uncertainty in the Lee–Carter Mortality Model', *International Journal of Forecasting*, 41(2): 781-797.