DISCUSSION PAPER PI-1704

Longevity Risk and Capital Markets: The 2015-16 Update

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September 2017

ISSN 1367-580X

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Longevity Risk and Capital Markets: The 2015-16 Update

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28 September 2017

This Special Issue of *Insurance: Mathematics and Economics* contains 16 contributions to the academic literature all dealing with longevity risk and capital markets. Draft versions of the papers were presented at *Longevity 11: The Eleventh International Longevity Risk and Capital Markets Solutions Conference* that was held in Lyon, France on 8-9 September 2015. It was hosted by Institut de Science Financière et d'Assurance (ISFA), Université Lyon 1, Lyon, and co-hosted by Laboratoire de Science Financière et d'Assurances, Lyon; Laboratoire de Probabilités et Modéles Aléatoires, Université Pierre et Marie Curie, Paris; Pensions Institute, Cass Business School, City University of London, UK; and the LoLitA (Longevity with Lifestyle Adjustments) ANR research project team. It was sponsored by Prudential Financial, SCOR, Société Générale Corporate and Investment Banking, the Society of Actuaries (SOA), EY, Milliman, Reinsurance Group of America, Aon Benfield, Guy Carpenter, PRIM'ACT, and SINALYS.

Longevity risk and related capital market solutions have grown increasingly important in recent years, both in academic research and in the market we refer to as the new Life Market, i.e., the capital market that trades longevity-linked assets and liabilities.[1] 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 counterpoising 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 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 and mortality (or *q*-) forward contracts. The aim of the *International Longevity Risk and Capital Markets Solutions Conferences* is to bring

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[1] Blake et al. (2013).

together academics and practitioners from all over the world to discuss and analyze these exciting new developments.

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

The second conference (*L2*) was held in April 2006 in Chicago and hosted by the Katie School at Illinois State University.[2] 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 pension liabilities of UK corporations. 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.[3] 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.

The third conference (*L3*) was held in Taipei, Taiwan on 20-21 July 2007. It was hosted by National Chengchi University.[4] 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 ageing 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.[5] 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;[6] the world's first publicly announced longevity swap between Swiss Re and the UK life

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

[3] 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 bulk purchase annuities (BPAs) 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. The world's first specialist buy-out company was Paternoster which was established in the UK in 2006. This was closely followed by the Pension Insurance Corporation (also in 2006) and Lucida and Rothesay Life (both 2007). Paternoster executed the first buy-out in November 2006 of the Cuthbert Heath Family Plan, a small UK plan with just 33 members. It also executed the first pensioner buy-in with Hunting PLC in January 2007. Paternoster was bought by Rothesay Life in 2011.

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

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

[6] www.lifemetrics.com

office Friends' Provident in April 2007 (although this was structured as an insurance or indemnification contract rather than a capital market transaction).

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.[7] 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.[8]

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[9] 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 assumes counter-party credit risk. Forty eight longevity swaps were 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).[10] 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, covering £16bn of pension liabilities, was the longevity swap for the British Telecom (BT) Pension Scheme, arranged by the Prudential Insurance Co of America 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 the accounting value of the liabilities which highlighted the attraction of using cheaper alternatives, such as longevity swaps.

The fourth conference (*L4*) was held in Amsterdam on 25-26 September 2008. It was hosted by Netspar and the Pensions Institute.[11] In 2008, Credit Suisse initiated a

[7] 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.

[8] In 2010, National Financial Partners became the sole owner of ILS/ILA.

[9] Coughlan et al. (2007).

[10] www.artemis.bm/library/longevity_swaps_risk_transfers.html

[11] The conference proceedings for *L4* were published in the February 2010 issue of *Insurance: Mathematics and Economics.*

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

The fifth conference (*L5*) was held in New York on 25-26 September 2009.[12] On 1 February 2010, the Life and Longevity Markets Association (LLMA)[13] was established in London. Its current members are Aviva, AXA, Deutsche Bank, J.P. Morgan, Morgan Stanley, Prudential 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.

The sixth conference (*L6*) was held in Sydney on 9-10 September 2010.[14] In December 2010, building on its successful mortality catastrophe Vita bonds and taking into account the lessons learned from the failed 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 are 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.

In January 2011, the Irish government announced that it would issue bonds that allow the creation of sovereign annuities. 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 have 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

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

[13] www.llma.org

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

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 2011, Willis Towers Watson (WTW) introduced the pension captive structure. A scheme executes a pensioner buy-in with a standard insurer, but then the insurer reinsures the buy-in back to a captive owned by the sponsor. Captives can provide a cost-effective solution compared with either a traditional buy-in or directly running the scheme over the longer term. This is because there can be a more efficient blending of investment management services with insurance, combined with a more effective disaggregation of risks and hence a more capital-efficient management of those risks. The first scheme to use it was Coca Cola.[15]

In December 2011, Long Acre Life entered the market to offer cheaper pension insurance solutions to larger schemes with liabilities above £500 million. Under these solutions companies offload their pension plans to an insurance vehicle in which they also invest and so share the profits along with external investors: the target return is 15% p.a. In January 2012, Legal & General (L&G) began offering longevity insurance (in the form of deferred buy-ins) for the 1,000 smaller schemes with liabilities in the range £50-£250 million. In February 2012, Punter Southall, a medium-sized UK pension consultant, adopted PensionsFirst's pension liability and risk management software (PFaroe) to automate the production of actuarial valuations and hence cut costs for pension plans, particularly small ones. In the same month, another medium-sized pension consultant, Hymans Roberton, launched a pension de-risking monitoring service which compares the costs of a full buy-out with the costs of a buy-in covering only pensioner members and the costs of a longevity swap.

In April 2011, the International Society of Life Settlement Professionals (ISLSP)[16] formed a life settlement and derivatives committee and announced that it was developing a life settlement index. The purpose of the index is 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 is 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 buy-in deal in the US took place in May 2011 between Hickory Springs Manufacturing Company and Prudential (US) ($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 organisational 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

[15] Willis Towers Watson (2017) *Key themes in the longevity hedging and bulk annuity market: De-risking report 2017*.

[16] www.islsp.org

buy-in and buy-out quotes directly from providers, including American General Life Companies, MetLife, Pacific Life, Principal Financial Group, Prudential (US), Transamerica and United of Omaha.

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

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

In February 2012, Deutsche Bank executed a massive €12 billion index-based longevity solution 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 is out of the money, the amount of longevity risk actually transferred is far less than that suggested by the €12 billion notional amount. Nonetheless, the key driver for this transaction from Aegon's point of view was the reduction in economic capital it achieved. Most of the longevity risk has been passed to investors in the form of private bonds and swaps.

In June 2012, General Motors Co. (GM) announced a huge deal to transfer up to $26 billion of pension obligations to Prudential (US). 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.[18] 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 $3.6 billion buy-out of the pension obligations of its white-collar retirees. Also in October 2012, Verizon Communications executed a $7.5 billion bulk annuity buy-in with Prudential (US). The buy-out deals in the U.S. in 2012 amounted to $36 billion.

The buy-outs for private sector pension plans had all involved plans that were closed to future accrual. However, in March 2012, PIC executed the first buy-out of a plan open to future accrual: the sponsoring employer, the high-tech manufacturer Denso, will pay PIC an annual premium based on the number of active members and their salaries, but PIC will assume all the liabilities. PIC had previously conducted an innovative buy-in in May 2011 with the London Stock Exchange's defined benefit pension plan which not only insured current pensioner members, but will also automatically insure active and deferred members when they reach retirement.

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

[18] In fact, the lump sum is only being offered to limited cohorts of plan members.

The eighth conference (*L8*) was held at the University of Waterloo, Ontario, Canada on 7-8 September 2012.[19] In June of that year, the OECD released the first edition of *Pensions Outlook*. This called on governments to kick-start the creation of a functional longevity risk market and consider issuing longevity bonds, without which the annuity market is unlikely to work well. In September 2012, Swiss Re released a report entitled *A mature market: Building a capital market for longevity risk*. The report called for the development of a capital market for longevity risk. It said that 'Society's longevity risk could be tackled to a greater extent if reinsurers were able to expand their capacity, and this could be done by encouraging capital market investors to invest in longevity instruments. …The main challenges include achieving transparency in measuring the risk and potential liability, building a secondary market, increasing investor education, providing the right level of return and regulation'.[20]

In December 2012, the enhanced buy-in market opened for business in the UK for defined benefit pension schemes. An enhanced buy-in is where a scheme's trustees buy a group annuity as in investment of the scheme, where some or all of the members covered by the policy are medically underwritten. Medical underwriting, which is now commonplace in the individual annuity market (i.e., in relation to defined contribution pensions), has the potential to reduce the cost to the scheme of the longevity hedge compared with standard annuities, on the grounds that certain members might have lower than average life expectancy as a result of their lifestyle or some serious life-shortening illness. The market was introduced by two specialist insurers, Partnership and Just Retirement, but other larger insurers followed, e.g., L&G which offers a Large Individual Defined Benefit Annuity (LIBDA) service.

In February 2013, the first medically underwritten bulk annuity (MUBA) transaction was executed in the UK by Partnership.[21] 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. L&G transacted a £230m medically-underwritten buy-in in December 2015 with the Kingfisher Pension Scheme, covering 149 high-value members. 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 – all of which perform MUMS (medically underwritten mortality studies). 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, i.e., from 5% to 12.5% of the market.[22] In April 2016, the two largest UK medical underwriters, Partnership and Just Retirement – which both entered the market in 2012 – merged to form Just valued at £16bn. In December 2016, Just

[19] The conference proceedings for *L8* were published in the *North American Actuarial Journal* (Volume 18(1), 2014).
[20] http://www.swissre.com/media/news_releases/nr_20120924_capital_market_longevity.html
[21] Harrison and Blake (2013).
[22] Hunt and Blake (2016).

executed a £110m medically underwritten buy-in with the Land Securities Group of Companies' defined benefit pension fund.

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 modelling 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 as part of a deal that moved $800m in pension obligations off SPX's balance sheet.

The ninth conference (*L9*) was held in Beijing, China on 6-7 September 2013.[23]

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 risk's 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[24] 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 realised 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 longevity risk transfer to capital markets investors and reinsurers, including SCOR. Société Générale was the intermediary in the €1.4 billion deal and Risk Management Solutions (RMS) was the modelling agent.[25] Also in December 2013, the Joint Forum reported on the results of its consultation on

[23] The conference proceedings for *L9* were published in *Insurance: Mathematics and Economics* (Volume 63 (July), 2015).

[24] International Swaps and Derivatives Association.

[25] RMS has developed a Longevity Model which was built by a team with expertise in epidemiology, mathematical biology, genetics, biostatistics, financial engineering, public health policy and medical science. RMS describes its model as a 'structural meta-model of geroscience advancement'.

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)).

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 defined benefit 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 accounting value of the liabilities – equivalent to £32 per £1 p.a. of pension.[26] The comparable costs in Ireland, the US 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 of pensions in payment 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.[27]

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. A second deal – this time with the UK pension scheme of the Italian tyre company Pirelli – was executed in August 2016 for £600m.

The tenth conference (*L10*) was held at Universidad Diego Portales in Santiago, Chile on 3-4 September 2014.[28]

In December 2014, WTW 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 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 uses 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. WTW introduced the first tracking software system to follow live insurer pricing, sending alerts when a scheme closes in on a target price.

[26] Towers Watson (2015) *Corporate Briefing*, April.
[27] Mercer uses the RMS Longevity Risk Model.
[28] The conference proceedings for *L10* were published in the *Journal of Risk and Insurance* (Volume 84(S1), April 2017).

There is evidence of increasing demand from reinsurance companies for exposure to large books of pension annuity business to offset the risk in their books of life insurance.[29] For example, in July 2014, Warren Buffett's Berkshire Hathaway agreed to a £780m quota-reinsurance deal with the Pension Insurance Corporation. Similarly, in August 2014, Delta Lloyd executed a €12bn longevity swap with RGA Re, while AXA France executed a €750m longevity swap with Hannover Re.

In March 2014, the UK insurer 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 scheme, a subsidiary of AkzoNobel. The deal uses 'umbrella' contracts which enables the scheme to add further liabilities onto the original contract.[30] In December 2014, L&G announced the largest ever UK buy-in valued at £2.5bn with US manufacturer TRW. In fact, in 2014, TRW became the first global corporation to simultaneously complete three de-risking transactions in three different countries: the UK, the US and Canada. Also in 2014, the Aviva Staff Pension Scheme completed the first limited recourse longevity swap, involving £5 billion in liabilities and 19,000 participants, 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 alone (covering buy-outs, buy-ins and longevity swaps) was £35bn, a significant proportion of which is accounted for by the £16bn BT longevity swap. To complete the transaction, the BT scheme created its own captive insurer located in Guernsey, which insured the longevity risk. The captive insurer then reinsured the risk in a fully collateralized arrangement. The scheme's immense scale and advanced capabilities helped it to become the first to execute such a transaction. Captive and limited recourse transactions have dominated the market since 2014.

In response to the announcement by the UK finance minister (George Osborne) in his Budget Speech on 19 April 2014, that UK pension scheme members no longer needed to buy annuities when they retired (which resulted in an immediate fall in annuity sales of more than 50%), a number of traditional annuity providers, including Scottish Widows, reported that they were considering entering the bulk annuity market.

In November 2014, the Longevity Basis Risk Working Group (2014) of the Institute & 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. 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 systemic risk of increased liabilities resulting from members living longer than expected. It had hitherto been difficult to assess how effectively an index-based longevity swap could reduce the longevity risk in a particular insurance book or pension

[29] The biggest buyers of longevity risk at the present time are global reinsurers. Nevertheless, according to Hannover Re: "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).
[30] By October 2016, the ICI scheme had completed 11 such deals – with L&G, Prudential (UK) and Scottish Widows – with a total value of £8bn, saving the parent company over £100mn in costs.

scheme. The methodology they developed 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 May 2016, a follow-up study – to be carried out by Macquarie University, Australian National University, Mercer Australia, and the University of Waterloo in Ontario – was announced. The purpose is to design a 'readily applicable methodology' for use with longevity risk indices: 'Such indices are often used in pension benefits and annuitant liabilities, as well as in providing actuaries with key data, …but the problem of the existence of basis risk remains unsolved.'

In March 2015, the UK government announced that it would introduce a new competitive corporate tax structure to allow Insurance Linked Securities to be domiciled in the UK. In May 2015, Rothesay Life, the insurance company owned by Goldman Sachs, bought out the liabilities of Lehman 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 Life 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 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%.[31] Deferred members are the most expensive to insure, since their life expectancy is the most uncertain, given their younger ages – yet they comprise 45% of the membership of UK schemes (i.e., 4.9m members).[32]

The largest buy-out to date in the UK was for the Philips Pension Fund which in November 2015 completed a full buy-out of the pension benefits of 26,000 members

[31] *Financial News*, 28 March–3 April 2016. The main objective of Solvency II is to value all assets and liabilities on a market-consistent basis and to ensure that the regulatory capital that insurance companies hold reflects all the risks on their balance sheets. The capital needs to be sufficient to guarantee that an insurance company can survived a series of prescribed stressed events over the course of one year with a 99.5% probability. One example of a stress is a sudden 20% reduction in mortality rates across all ages: for a 65-year old UK male, this corresponds to a 2 year increase in life expectancy or a 7% increase in pension liabilities. A consequence of the market-consistent approach is that both assets and liabilities are more prone to market volatility, although with long-term liabilities, such as annuities and buy-outs, short-term asset price volatility can be partially offset by 'matching adjustments'. The insurer would need to allocate a specific pool of assets to the liability, where the assets are selected to match the cash-flow characteristics of the liability. The assets need to be matched for the entire term of the liability, in which case the liability can be valued using a higher discount rate than prescribed by the regulator (European Insurance and Occupational Pensions Authority, EIOPA), resulting in the insurer holding lower 'own funds' to back the liability. However, because of longevity risk, the asset match can never be perfect and this has the effect of raising the level of own funds. A particular example is non-pensioner members of pension schemes who have greater longevity risk than pensioner members, leading to a lower adjusted discount rate. There is also greater optionality with non-pensioner members (such as early retirement and commutation options) and this also reduces the discount rate and, by raising the level of own funds, increases the cost of providing deferred annuities to the pension scheme or buying out this segment of the pension scheme. Insurance companies increasingly invest in long-term assets like infrastructure and reverse mortgages to reduce asset price volatility, and in corporate bonds to benefit from the credit and illiquidity premia embodied in their higher returns compared with government bonds. They also make increasing use of reinsurance to reduce the volatility of liabilities.

[32] The Pension Regulator and the Pension Protection Fund, *Purple Book 2015*.

valued at £2.4bn with the Pension Insurance Corporation. An interesting feature of this deal was that a buy-out was combined with a longevity hedge. The longevity risk was simultaneously reinsured with Hannover Re. Another interesting feature was that it covered both retired and deferred members, with the latter's benefits valued at £1bn.

An important new longevity-linked product that took off in the UK in 2015 was the lifetime mortgage (also known as equity release or reverse mortgage). This allows individuals to release equity in their homes to fund their retirement without downsizing. L&G, for example, set up L&G Home Finance for this purpose and in its first year completed more than £400mn lifetime mortgage sales.

In 2015, L&G directly 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: Prudential Financial 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,[33] 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 June 2015, Delta Lloyd did a second €12 billion longevity swap with RGA Re. In July 2015, Aegon did one valued at €6 billion 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 scheme's data. It collects prices provided monthly by insurers in the bulk market, based on scheme 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 scheme 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'.

In April 2016, WTW 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,

[33] Sun Life Financial also uses the RMS Longevity Risk Model.

then the current price of longevity of risk transfer products would be too high. In 2016, there were a total of £8.6bn in buy-outs and buy-ins and £1.6bn in longevity swaps.[34]

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 it had set up for the plan in 2014. This is the first example 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.[35] 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. This made sense, given it already does this on its existing book of individual annuities which are backed by £12bn of assets. The timing was critical too. 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 its regulator (the Prudential Regulation Authority) 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.[36]

In 2016, the UK office for National Statistics reported that longevity improvements rates have slowed down since 2011, especially at high ages; but it is not yet clear whether this is a genuine change in trend or the result of overestimating the number of older people at the time of the 2001 census, which had the effect of artificially reducing the high-age mortality rate between 2001 and 2011.[37] Nevertheless, it prompted a debate in the UK in 2016 about the reliability of life expectancy projections. Mortality improvements in UK males averaged 1% over the preceding three years, compared with 3% in the decade before. Tim Gordon, head of longevity at Aon Hewitt said: 'This is the most extreme reversal in mortality improvement trends seen in the past 40 years. What was initially assumed by many actuaries to be a blip is increasingly looking more like an earlier-than-expected fall-off in mortality improvements. The industry is currently trying to digest all the implications of this emerging information and – inevitably – it is taking time to feed through into insurance and reinsurance pricing'. Others say that this could just be 'noise'. Matt Wilmington, director of pension risk transfer at L&G, points out that: 'Two years doesn't make a trend – it's very volatile from year to year. If we had another five years where we saw far fewer deaths than expected, then we might start to see fairly significant changes, but where we are now, there's not enough to persuade us – or many of the pension plans we work with – that there's a vast reversal in trend in terms of life expectancy just yet'. Tim Gordon also warns against attempts to time the market: 'Timing the longevity market in the same way you would time an equity market is extremely difficult, and plans could be in danger of missing opportunities now if they did that'.[38] Nevertheless, the difference in

[34] Pensionfundsonline, 15 December 2016.
[35] Solvency II came into effect at the beginning of 2016.
[36] Stephanie Baxter (2017) How PGL's longevity swap was converted into a buy-in, *Professional Pensions*, 10 April.
[37] Anthony Hilton (2016) Life line, *Pensions World*, May. See also Cairns *et al.* (2016).
[38] Quoted in Jenna Gadhavi (2017) Does the bell toll for longevity swaps?, *Engaged Investor*, 13 January.

mortality improvement rates is equivalent to a difference in liabilities of 1% or four months of pension payments for every retiree: UK pension liabilities would be £25bn lower if the future mortality improvement rate were 1% rather than 3%.[39] Consultant Barnett Waddingham has put forward the suggestion that higher health and social care spending between 2000 and 2010 may have caused a blip in longevity estimates by accelerating improvements. Since 2009, health spending has been flat in real terms and there have been lower mortality improvements.[40]

2016 saw the beginning of a trend towards consolidation amongst insurance companies involved in the longevity risk transfer business in the UK. For example, Aegon sold its £9bn UK annuity portfolio to Rothesay Life and L&G in April and May, as part of a strategy to free up capital from non-core business. Part of the reason for this is the additional capital requirements under Solvency II which only the most efficient firms have the ability to absorb. Similarly, in September, Deutsche Bank sold its Abbey Life subsidiary to Phoenix Life, a consolidator of closed insurance books, for £935mn, as part of a planned programme of disposals aimed at restoring its capital base. There is an estimated £100bn of UK individual annuities in back books and further consolidation of these back books is anticipated. One striking example of this is the UK Prudential which is rumoured to be selling its £45bn UK annuity and pension liability businesses due to an inadequate return on capital and transferring that capital to its growing businesses in Asia. Reinsurance deals also increased in response to Solvency II. For example, Pension Insurance Corporation executed a £1.6 billion longevity reinsurance agreement with the Prudential Insurance Company of America in June 2016. Solvency II has also been blamed for some companies pulling out of the bulk annuities market altogether, a key example being the UK Prudential in January 2016.

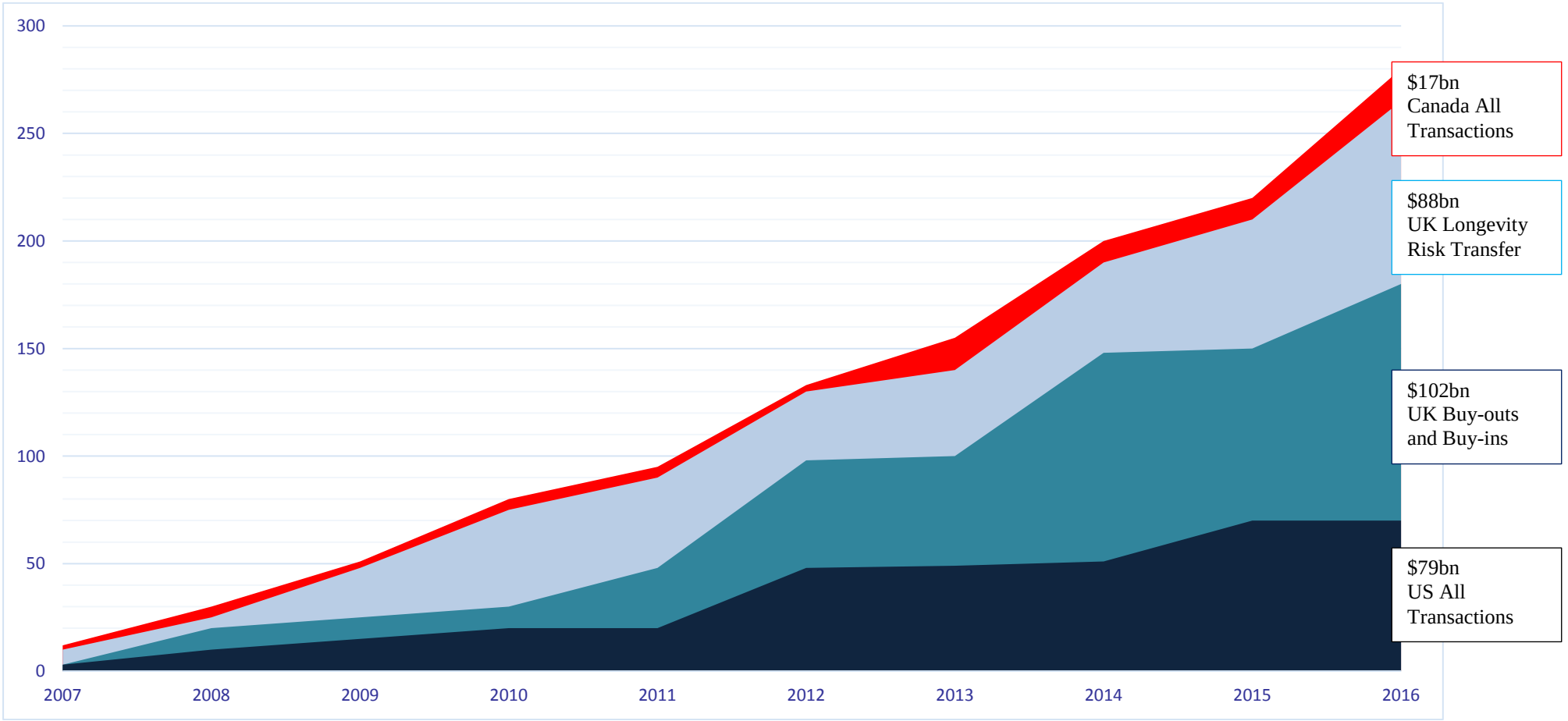
2016 also witnessed the increasing streamlining and standardization of contracts. This is particularly beneficial to small schemes below £100m. Previously, smaller schemes have been less attractive to insurers on account of the higher costs to the insurer of the pricing the transfer relative to profit. To circumvent this, consultants have begun offering services that allow smaller schemes to access improved pricing and better commercial terms using a standardised 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 schemes have also been prepared to use pre-negotiated contracts.[41]

Finally, 2016 was 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 1mn people. Yet this equates to just 5% of the £1.5trn of UK defined benefit (DB) pension assets and 3% of the £2.4trn of DB liabilities on a buy-out basis. In addition, there have been £60bn of longevity swaps.[42] Figure 1 shows the

[39] *Professional Pensions*, 26 January 2017.
[40] *Professional Pensions*, 29 March 2017.
[41] Willis Towers Watson (2017) *Key themes in the longevity hedging and bulk annuity market: De-risking report 2017*.
[42] LCP, *Professional Pensions* (15 December 2016 and 26 January 2017). Since 2007, some 92 buy-ins have been completed, worth a total of £30.6bn – see Table 1.

growth of the global market in longevity risk transfer between 2007 and 2016. A total of $280bn in transactions have been completed during this period.

Figure 1: Cumulative Pension Risk Transfers by Product and Country, 2007-16



Sources: LCP, Hymans Robertson, Prudential Financial, Daniel Ben-Ami (2016) Preparing for a jump in longevity, *Pensions & Investments Europe*, December.

In order to reduce the costs of de-risking, pension schemes are encouraged to perform some liability reduction exercises, the key ones being:[43]

- Enhanced transfer values (ETVs) – allow deferred members to transfer an uplifted value of their benefits to an alternative arrangement
- 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 scheme 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 RPI 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.

Innovation is a continuing feature of this market. Some examples include:[44]

- Buy-ins and buy-outs with deferred premium payments – to spread costs
- 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 scheme 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, 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
- 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 scheme or an unnamed scheme with 90 named pensioners valued at £50m)
- Longevity swaps for small pension schemes with liabilities of £50-100m – previously only available for medium (£100-500m) and large schemes (above £500m).
- Longevity swap to buy-in conversions – as pioneered by Phoenix Life in December 2016. Solvency II incentivises buy-in providers to hold longevity insurance, otherwise they pay an additional risk margin. This encourages buy-in providers to seek out schemes which already have a longevity hedge and encourage them to do a buy-in. Another driver is longevity swap providers that have withdrawn from this market – such as Deutsche Bank and Credit Suisse – but are still responsible for running off their existing swaps. They might have an incentive to encourage the

[43] Professional Pensions (2016) *Risk Reduction and the Extent of Trust in Pension Scheme Advisors and Providers,* June, p.26.

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

associated pension plan to novate the swap to a buy-in provider and hence extinguish their liability.[45]

- 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; or the option for a contract to be novated to another insurer if a scheme wants to buy-in or buy-out benefits with another insurer in the future.
- Combining liability management solutions (such as interest rate and inflation swaps) and bulk annuities in a buy-out – so instead of completing liability management before considering a buy-out, schemes 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.

These are all innovations in the space linking pension schemes and insurance companies designed to ease the transfer of pension liabilities (or at least the longevity risk in them) from pension schemes to insurance companies. But there is now an increasing sign of 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'.[46]

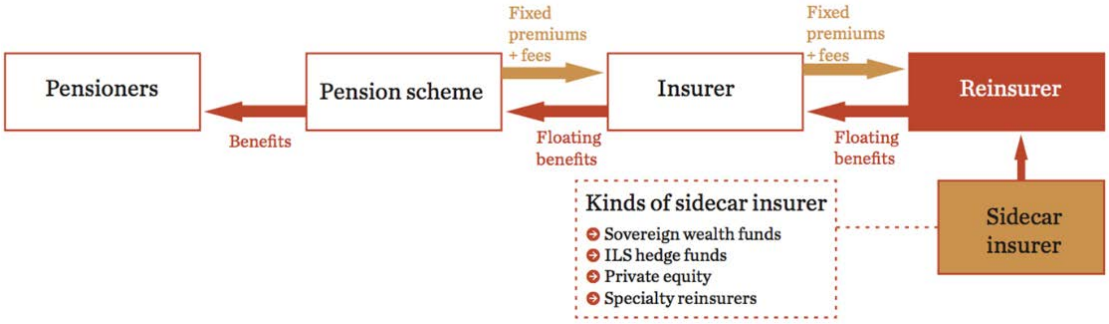
In April 2017, the International Monetary Fund (IMF) released a new edition of its *Global Financial Stability Report*. Chapter 2 ('Low Growth, Low Interest Rates, And Financial Intermediation') suggests that DB pension funds across the globe might have to cut benefits 'significantly' in the long term 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 buyouts. 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'.

[45] Stephanie Baxter (2017) Converting longevity swaps into bulk annuities: The next de-risking innovation?, *Professional Pensions*, 13 April.

[46] Martyn Phillips, Mercer (quoted in Professional Pensions (2016) *Risk Reduction and the Extent of Trust in Pension Scheme Advisors and Providers*, June, p.28).

The only long-term solution to this capacity constraint is to bring in new investors from the capital markets (i.e., to transfer the risk to the capital markets). These investors will include sovereign wealth funds, ILS hedge funds and private equity investors. But these investors need some assurance that they are not going to be sold a 'lemon'. There have been many attempts over the last decade to provide this assurance – without any real success. One potential solution to this problem was discussed in a plenary session at the L12 conference, namely insurance sidecars – which are a way to share risks with new investors when the latter are concerned about the ceding insurer having an informational advantage – see Figure 2.[47]

Figure 2: Sidecar investing



Source: Prudential Retirement

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), 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), Chen et al. (2013), Shen and and Siu (2013), Blake et al. (2014), Denuit et al. (2015), Hunt and Blake (2015), Milevsky and Salisbury (2015), Yang et al. (2015), Chen et al. (2017), Lin et al. (2017b)).
- 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)) and specifically survivor/longevity swaps (e.g., Dowd et al. (2006), Wang et al. (2013, 2015)), survivor/longevity forwards and swaptions (e.g., Dawson et al. (2010)), *q*-forwards (e.g., Deng et. al. (2012), Barrieu and Veraart (2016)), mortality options (e.g., Milevsky and Promislow (2001)), and guaranteed annuity options (e.g., Gao et al. (2015))

[47] Kessler et al. (2016)

- Pricing longevity risk (e.g., Olivieri and Pitacco (2008), Bayraktar et al. (2009), Chen et al. (2010), Li (2010)).
- 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))
- Longevity and mortality indices (e.g., Denuit (2009), Li et al. (2011), Chan et al. (2014), Tan et al. (2014))
- 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), Wills and Sherris (2010), Lane (2011), Mazonas et al. (2011), Biffis and Blake (2013, 2014), Blake et al. (2013), Yang and Huang (2013), Michaelson and Mulholland (2014), MacMinn and Brockett (2017))
- 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), 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), Cairns (2013), Cox et al. (2013a,b), Qiao and Sherris (2013), Cairns et al. (2014), Zelenko (2014), Zhu and Bauer (2014, Li et al. (2017), Zhou and Li (2017)))
- Mortality modeling, mortality term structure[48] modelling, and mortality forecasting (e.g., Hobcraft et al. (1982), Booth et al. (2002a,b), Brouhns et al. (2002a,b, 2005), Renshaw and Haberman (2003a,b, 2006, 2008), Currie et al. (2004), Biffis (2005), Czado et al. (2005), Delwarde et al. (2007), Cairns et al. (2006b, 2008a,b, 2009, 2011a), Koissi et al (2006), Pedroza (2006), Bauer et al. (2008), Blake et al. (2008), Gourieroux and Monfort (2008), Hari et al. (2008), Kuang, et al. (2008a,b), Haberman and Renshaw (2009, 2011, 2012, 2013), Hatzopoulos and Haberman (2009, 2011), Li et al. (2009), 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,c, 2016), Lin and Tzeng (2010), Murphy (2010), Yang et al. (2010), Coelho and Nunes (2011), D'Amato et al. (2011), 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), Alai and Sherris (2014b), Aleksic and Börger (2012), D'Amato et al. (2012a,b), Hainaut (2012), Hyndman et al. (2013), Kleinow and Cairns (2013), Mitchell et al. (2013), Nielsen and Nielsen (2014), Hunt and Blake (2014), Mayhew and Smith (2014), Villegas and Haberman (2014), Danesi at al. (2015), Hunt and Villegas (2015), Li et al. (2015), O'Hare and Li (2015), Tomas and Planchet (2015), Berkum et al. (2016), Currie (2016))[49]

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

[49] In December 2015, the UK Continuous Mortality Investigation (CMI), a subsidiary of the Institute and Faculty of Actuaries, reported that UK mortality improvements over the previous four years have been much lower (close to zero) than equivalent periods over the previous 40 years (the average rate between 2001 and 2011 was 2.4% p.a.), raising the question of whether mortality improvements have at last begun to slow down. The 2016 release of the CMI's mortality forecasting model – which is used by over 90% of UK pension funds to make their mortality projections – reports that there is increasing evidence that the

- Multi-population mortality modelling (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), Börger and Ruß (2012), D'Amato et al. (2014), Zhou et al. (2014), Chen et al. (2015), Kleinow (2015), Li et al. (2015), Biffis et al. (2017), Milidonis and Efthymiou (2017), Zhu et al. (2017))
- Cause-of-death mortality modelling (e.g., Hanewald (2011), Alai et al. (2014), Gourieroux and Lu (2015))
- 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))
- Reverse mortgages (e.g., Wang et al. (2008), Huang et al. (2011), Yang (2011), Alai et al. (2014a), Kogure et al. (2014), Shao et al. (2015))
- Longevity risk in investment portfolios (e.g., Milevsky and Young (2007), Menoncin (2008), Horneff et al. (2008, 2009, 2010, 2015), Huang et al. (2012), Maurer et al. (2013), Ai et al. (2017))
- Longevity risk in pension plans and pension systems (e.g., Aro (2014), Bisetti and Favero (2014), Donnelly (2014), Lin et al. (2014, 2015, 2017a), Ai et al. (2015), Wan and Bertschi (2015), Lin et al. (2017a)).

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.[50] 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 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.

low level of mortality improvements in the UK since 2011 may be due to medium- or long-term influences instead of being a short-term blip. The effect could be to reduce the aggregate deficit in UK pension schemes from £530bn to £220bn.

[50] 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.

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 US Dodd-Frank (Restoring American Financial Stability) Act 2010 which prevented US banks and their affiliates from entering longevity swaps and synthetic trades in life settlements. At around the same time, however, a number of insurers and reinsurers entered the market, i.e., Prudential (US), SCOR and Munich Re. Despite these new entrants, 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 that time, it had 31,000 pensioners on its books and £1.4 billion 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 £3 billion, was sold to Rothesay Life for an undisclosed sum, bringing its total assets to £10 billion.

In December 2013, Goldman Sachs sold the majority of its stake in Rothesay Life to Blackstone (28.5%), Government of Singapore Investment Corporation (GIC) (28.5%), and MassMutual (7%), due to the new regulatory capital requirements faced by banks and insurers.

The new Trump administration in the US has promised to repeal the 2010 Dodd-Frank Act and restore the 1933 Glass-Steagall Act. The former Act, introduced in the aftermath of the Global Financial Crisis and 2,300 pages long, has cost US banks up to $36bn in regulatory costs and forced them to end proprietary trading, a key factor explaining why US banks exited from the longevity risk transfer market, except for those banks, such as Goldman Sachs, which had insurance company subsidiaries. The latter Act, just 37 pages long, would require the separation of the investment banking and retail banking arms of the largest Wall St banks. These changes might lead to US banks looking again at the longevity risk transfer market.

As with the previous conferences, *Longevity 11* consisted of both academic papers and more practical and policy-oriented presentations. The conference was addressed by the following keynote speakers:

- Denis Jacquat (Assemblée Nationale) who gave a presentation entitled ‘Longevity and Aging Issues in France: a Member of Parliament's Perspective’.
- Jessica Mosher (OECD) who discussed the findings of the 2014 OECD study ‘Mortality Assumptions and Longevity Risk – Implications for Pension Funds and Annuity Providers’.[51] One of the recommendations of the study was that ‘Governments should encourage the development of a market for instruments to hedge longevity, particularly index-based instruments, by facilitating transparency and standardization of longevity hedges in order to ensure the capacity for pension plans and annuity providers to continue to provide longevity protection to individuals’.

[51] dx.doi.org/10.1787/9789264222748-en

- Ronald Lee (University of California at Berkeley) in a presentation entitled 'Widening Socioeconomic Differences in Mortality and the Progressivity of Public Pensions and other Programs for the Elderly' discussed the results of the US National Academy of Sciences' study 'The Growing Gap in Life Expectancy by Income: Consequences and Policy Responses'. The study found that the top half of the income distribution has benefited much more from rising life expectancy than the bottom half, while widening mortality differentials have reduced the progressivity of public transfers substantially. Professor Lee argued that these points should be considered when designing policy responses to population aging.
- Tom Kirkwood (Newcastle University) gave a presentation called 'Why and How are We Living Longer?'. He began by pointing out that, contrary to widely held belief, the body is not programmed to age and die. Rather, the body is programmed for survival. However, there was no evolutionary pressure to invest in a body that might live forever. Ageing is caused by the accumulation of damage, particularly to the body's cells. Professor Kirkwood said we needed to address the following key questions: (a) Can we identify the precise factors contributing to the malleability of longevity and health in old age?, (b) Can we improve our understanding of age-related multi-morbidity?, (c) Can we use such knowledge further to promote health in old age and to reduce frailty and dependency?, and (d) What mechanisms do we need to set in place to track trends in incidence of age-related diseases?
- Laurent Schwartz (Ecole Polytechnique) talked on the subject of 'Cancer Mortality: Towards a Structural Change?'. Cancer treatments have so far been less successful than the treatments for other diseases. Dr Schwartz said the solution was to identify the combination of drugs that would be active against altered cancer cell metabolism. For example, one study showed long-term stabilization with IV Lipoicacid and low dose naltrexone. The current state of knowledge is that (a) cancer is most probably the simple consequence of mitochondrial inactivation and (b) Alzheimer's disease has a lot of common features with cancer.
- Andre De Vries (RGA) gave a presentation entitled 'Capital Motivated Longevity Transactions in Practice'. He introduced a product called the 'Longevity Shock Absorber' (LSA) which is designed to strike a balance between the costs and benefits to insurers using it. The LSA transfers remote (i.e., tail, but not extreme) longevity risk and thereby improves the insurer's capital position under Solvency II. It improves both sides of the Solvency Ratio, by increasing Own Funds and decreasing the Solvency Capital Requirement. The LSA has an attractive price relative to other capital management solutions.
- Guy Coughlan (Universities Superannuation Scheme) gave a talk called 'Longevity – it's academic' which analyzed the mortality and longevity characteristics of the members of the largest funded UK pension plan. The membership of the plan is large, geographically diverse, and yet reasonably homogeneous in terms of demographic profile. As such it provides a unique case study and interesting comparisons with other populations.
- Avery Michaelson (Société Générale Corporate and Investment Banking) talked about 'Indexed vs. Indemnity Longevity Hedges', based on the analysis in Michaelson and Mulholland (2014).

- Jean-Marie Robine (INSERM) provided an 'Update on the Adult Longevity Revolution'. The main findings are: (a) a dramatic increase in the number of centenarians, (b) both a compression and shifting of mortality, and c) an apparent limit to the maximum life span between 110 and 115.
- Mark Flint (SCOR) gave a presentation on 'The Impact of Recent Regulatory Change on the UK Individual Annuity Market'. The overwhelming tax incentive to use personal pension savings to buy an annuity was (effectively) removed from April 2015. Annuities are viewed as bad value by the media in the UK. The annuity market has fallen by around 60%, after peaking at over £12bn in 2012, but now appears to be stabilizing at the new lower level. A large proportion of annuities are still purchased without shopping around. Although there is significant uncertainty, initial signs are that annuities will continue to play a significant role under the new Pension Freedoms. Annuities and other products that enable insurance of longevity risk are likely to be rated by postcode and medical status in future (i.e. medically underwritten).
- Philip Simpson (Milliman) reported on 'Recent Developments in the UK Longevity Market': (a) a continuous relatively constant decline in male and female mortality rates, (b) some suggestion in recent years that the decline might be slowing down, and (c) a decline in deaths from circulatory diseases is the most significant disease-based contributor to improvement. Mr Simpson described the current state of the UK longevity market: (a) low bond yields and equity market volatility has made pension scheme buyouts seem expensive, (b) Solvency II is likely to make deals with insurers more expensive in the future, since insurers expect capital requirements under Solvency II (which came into effect at the beginning of 2016) to be higher than under the previous system, especially for new business, (c) insurers seeking to reinsure significant volumes of longevity risk both via longevity swaps and asset-based deals, (d) capital market transactions, as opposed to reinsurance, remain few and far between, and many banks have effectively withdrawn from the longevity market, and (e) most deals are on an indemnity basis with few index based transactions.
- Amy Kessler (Prudential Retirement) talked about the 'The Longevity Risk Transfer Market at $250bn – Innovation, Golobalization and Growth'. She pointed out that in the US, UK, Canada and the Netherlands $250bn in pension liabilities have been transferred to insurers and reinsurers since 2007. All kinds of companies were benefiting from flexible risk transfer solutions that secured member benefits and helped corporate sponsors achieve a lower risk future. Innovation has been crucial to recent growth as insurers and reinsurers have broken through the early barriers to large transactions by perfecting a full range of solutions for pension funds of all shapes and sizes. Globalization was just beginning with activity spreading to France, Germany, Switzerland, the Nordics, and Australia in the coming years.
- Finally, there were two round tables:
    - 'Big Data and Longevity' with Frederic Planchet (SAF Laboratory), Alexander Zhavoronkov (John Hopkins University) and Pierre-Henri Tavoillot (Paris Philosophy College)

- ‘Longevity and Long Term Care’ with Jean-Herve Lorenzi (Edmond de Rothschild), Serge Guerin (ESG) and Jean-Micheal Ricard (Siel Blue).

The academic papers that were selected by us as the editors of this Special Issue went through a refereeing process subject to the usual high standards of *Insurance: Mathematics and Economics.* They cover the following themes: mortality bonds, risk in pension plans and retirement income, the valuation of annuities and reverse mortgages, longevity risk hedging and sharing, cause of death mortality, and mortality modelling. We briefly discuss each of the 16 papers selected.

In ‘The Choice of Trigger in an Insurance Linked Security: The Mortality Risk Case’, Richard MacMinn and Andreas Richter begin by pointing out that in 2003, Swiss Re introduced a mortality-based security designed to hedge excessive mortality changes for its life book of business. The concern was mortality risk, i.e., the risk of premature death. The mortality risk due to a pandemic is similar to the property risk associated with catastrophic events such as earthquakes and hurricanes and the security used to hedge the risk is similar to a CAT bond. The authors look at the incentives associated with insurance-linked securities. They consider the trade-offs an insurer or reinsurer faces in selecting a hedging strategy and compare index and indemnity-based hedging as alternative design choices and ask which is capable of creating the greater value for stakeholders. Additionally, they model an insurer or reinsurer that is subject to insolvency risk, which creates an incentive problem, known as the judgment proof problem. The corporate manager is assumed to act in the interests of shareholders and so the judgment proof problem yields a conflict of interest between shareholders and other stakeholders. Given the fact that hedging may improve the situation, the analysis addresses what type of hedging tool would be best. The authors show that an indemnity-based security tends to worsen the situation, as it introduces an additional incentive problem. Index-based hedging, on the other hand, under certain conditions turns out to be beneficial and therefore dominates indemnity-based strategies. This result is further supported by showing that for the same sufficiently small strike price the current shareholder value is greater with the index-based security than the indemnity-based security.

In ‘Pension Risk Management with Funding and Buyout Options’, Samuel H. Cox, Yijia Lin and Tianxiang Shi show that there has been a surge of interest in recent years from defined benefit pension plan sponsors in de-risking their plans with strategies such as ‘longevity hedges’ and ‘pension buyouts’. While buyouts are attractive in terms of value creation, they are capital intensive and expensive, particularly for firms with underfunded plans. The existing literature mainly focuses on the costs and benefits of pension buyouts. Little attention has been paid to how to capture the benefits of de-risking within a plan’s financial means, especially when buyout deficits are significant. To fill this gap, the authors propose two options, namely a pension funding option and a pension buyout option, that provide financing for both underfunded and well-funded plans to cover the buyout risk premium and the pension funding deficit, if a certain threshold is reached.
To increase market liquidity, the authors create a transparent pension funding index, calculated from observed capital market indices and publicly available mortality tables as well as pension mandatory contributions, to determine option payoffs. A simulation based

pricing framework is then introduced to determine the prices of the proposed pension options. Numerical examples show that these options are effective and economically affordable. Moreover, sensitivity analyses demonstrate the reliability of the pricing models.

In 'The Effect of Longevity Drift and Investment Volatility on Income Sufficiency in Retirement', Les Mayhew, David Smith and Douglas Wright recall that, in 2014, the UK Government announced radical proposals which will allow people to withdraw money from their pension pot from age 55, 'how they want, subject to their marginal rate of income tax in that year'. The main effect of this change was to put more onus on the individual to make sure they have sufficient resources to last for their retirement, but it also removes the obligation to annutise their funds at any future age. This paper is concerned with how people can best use their pension pots by aligning them to their personal financial objectives and longevity risks. It finds that for most people annutising is *not* the best option except a few circumstances and that draw down is preferable, especially where there is a bequest and the individual has assets such as property to fall back on. These options are low risk if simple rules are followed but they are not a substitute for professional advice and should only be used in conjunction.

In 'Valuation of Longevity-linked Life Annuities', Jorge Miguel Bravo and Najat El Mekkaoui de Freitas show that the fair value of a pure longevity-linked life annuity can be decomposed into a traditional fixed annuity and a basket of European-style longevity (call and put) options of different maturities with an underlying asset equal to a longevity-index and strike equal to the minimum (initial) guaranteed amount. The embedded longevity put (call) options give the annuity provider (annuitant) the right to periodically adjust the benefit payments downwards (upwards) if the observed survivorship rates are higher (lower) than those predicted at the contract initiation, transferring part of the longevity risk to the annuitant. Alternative decompositions for the payout stream of a capped longevity-linked life annuity are also explored. The authors incorporate capital market risk and assess how individuals with different risk aversion and subjective time preferences value the stochastic payout stream of both index-linked and participating contract structures. They discuss the valuation of the embedded longevity options using a risk-neutral simulation approach. The paper revisits and expands previous results on the problem of designing and pricing life annuity contracts which aim at sharing longevity and investment risk between annuity provider and annuitants within the context of building post-retirement income.

In 'Unisex Pricing of German Participating Life Annuities – Boon or Bane for Customer and Insurance Company?', Sandy Bruszas, Barbara Kaschützke, Raimond Maurer and Ivonne Siegelin explore how the European Union requirement for gender-neutral premiums and the new rules for surplus participation in participating life annuities (PLAs) affect an insurance company's profitability and policyholder's wellbeing. The authors analyse real data observed for annuity prices in the German market followed by an examination of the impact of the unisex calculation, allowing for different assumed and realised gender compositions. They develop a realistically calibrated asset and liability model for a PLA with stochastic mortality, interest rates, and equity returns. They show that for males, the disadvantages of a PLA's unisex pricing as compared to a gender-specific calculation are substantially lower if measured using a lifetime utility framework

that accounts for both distributed surpluses and stochastic mortality. For the insurance company, the gender mix composition turns out to be less important than the capital market effect. Moreover, PLAs turn out to be an efficient means to share actual mortality experience between insurance company and the annuitant, and can be, at least to a certain extent, considered a substitute for indemnity longevity hedge.

In 'Valuation of Variable Long-term Care Annuities with Guaranteed Lifetime Withdrawal Benefits: A Variance Reduction Approach', Ming-hua Hsieh, Jennifer L. Wang, Yu-Fen Chiu, and Yen-Chih Chen propose a new product, the Variable Life Care Annuity with Guaranteed Lifetime Withdrawal Benefits (LCA-GLWB), and design an efficient valuation algorithm. This innovative product provides a comprehensive retirement solution for both longevity risk and long-term care protection. It includes the benefits of guaranteed income streams with downside risk protection and long-term care expenses for retirees. However, the valuation of this type of product is both complex and time-consuming. In this paper, the authors propose a Monte Carlo valuation algorithm that uses the variance reduction technique. The numerical results indicate that the proposed valuation algorithm is very efficient under a broad range of asset return models. The proposed algorithm provides a general approach for the rapid valuation of similar products and can help provide life insurance companies offering innovative products with an appropriate valuation tool.

In 'Profitability and Risk Profile of Reverse Mortgages: A Cross-System and Cross-Plan Comparison', Yung-Tsung Lee, Ko-Lun Kung and I-Chien Liu conduct a cross-system and cross-plan comparison of reverse mortgages. They compare the systematic distinctions and analyze the risk and profitability of reverse mortgages in two prominent types of market arrangements: (a) a market where a public external insurer exists (i.e., the Home Equity Conversion Mortgage program in the U.S. market); and (b) a market where an external insurer is absent (i.e., the Australian market). Two typical payment plans, the lump-sum and annuity payments, are examined and compared using stochastic dominance criteria. The paper provides a complete framework for analysing the profitability and risk profile of reverse mortgage products. It argues that modern solvency capital requirements, such as Solvency II, may depress the loan-to-value ratio and the intervention of government may be necessary. The authors also demonstrate that the lender prefers lump-sum products and this may explain why such products dominate the market in practice. The study can help financial institutions and governments understand the properties of reverse mortgages and hence help to develop a reverse mortgage market.

In 'A Strategy for Hedging Risks Associated with Period and Cohort Effects Using *q*-Forwards', Yanxin Liu and Johnny Siu-Hang Li argue that the stochastic nature of future mortality arises from both period (time-related) and cohort (year-of-birth-related) effects. Existing index-based longevity hedging strategies mitigate the risk associated with period effects, but often overlook cohort effects. The negligence of cohort effects may lead to sub-optimal hedge effectiveness, if the liability being hedged is a deferred pension or annuity which involves cohorts that are not covered by the data sample. In this
paper, the authors propose a new hedging strategy that incorporates both period and cohort effects. The resulting longevity hedge is a value hedge, reducing the uncertainty surrounding the τ -year ahead value of the liability being hedged. The proposed method

is illustrated with data from the male population of England and Wales. It is found that the benefit of incorporating cohort effects into a longevity hedging strategy depends heavily on the persistence of cohort effects and the choice of *q*-forwards.

In 'Replicating Intergenerational Longevity Risk Sharing in Collective Defined Contribution Pension Plans using Financial Markets', Enareta Kurtbegu argues that intergenerational risk sharing is often seen as a strong point of the Dutch pension system. The ability to absorb financial and actuarial shocks through the funding ratio allows for the smoothing of returns over generations. Nevertheless, it implicitly means that generations subsidize each other, which has its disadvantages, especially in the light of incomplete contracts and situations of hard regulation constraints. The paper highlights the advantages of intergenerational risk sharing as a main characteristic in certain collective pension plans, investigating if and how much of this can be replicated by individual participation in the market. Using a stylized model based on different pension plans such as 'hard'/'soft' defined benefit, collective/ 'pure' defined contribution, the author identifies the effects of an increase in life expectancy as one of the most important demographic shocks. The existence of regulatory constraints modifies agents' behavior so that they tend to choose individual investment to ensure their retirement savings. In the absence of regulatory constraints, individual investment under-performs pension fund performance. Thus, choosing collective participation is more rational.

In 'Cause of Death Mortality: What Can be Learned from Population Dynamics', Séverine Arnold, Alexandre Boumezoued, Héloïse Labit Hardy and Nicole El Karoui analyse cause-of-death mortality changes and its impacts on whole population evolution. The study combines cause-of-death analysis and population dynamics techniques. The aim is to measure the impact of cause-of-death reduction on the whole population age structure, and more specifically on the dependency ratio which is a crucial quantity for pay-as-you-go pension systems. Whereas previous studies on causes of death focused on mortality indicators, such as survival curves or life expectancy, the approach here provides additional information by including birth patterns. As an important conclusion, numerical results based on French data show that populations with identical life expectancies can present important differences in their age pyramid resulting from different cause-specific mortality reductions. Sensitivities to fertility level and population flows are also given.

In 'Using the Taiwan National Health Insurance Database to Model Cancer Incidence and Mortality Rates', Jack C. Yue, Hsin-Chung Wang, Yin-Yee Leong and Wei-Ping Su show that increasing cancer incidence and mortality rates in Taiwan have worsened the loss ratio of cancer insurance products and created a financial crisis for insurers. The authors used data from the Taiwan National Health Insurance Research Database to evaluate the challenge of designing cancer insurance products. They found the Lee-Carter and APC models have the smallest estimation errors, and the CBD and Gompertz models are good alternatives to explore the trend of cancer incidence and mortality rates, especially for the elderly people. The loss ratio of Taiwan's cancer insurance products is expected to grow and this can be deemed as a form of longevity risk.

In ‘Do Actuaries Believe in Longevity Deceleration?’, Edouard Debonneuil, Frédéric Planchet and Stéphane Loisel ask the question: As more and more people believe that significant life extensions may come soon, should commonly used future mortality assumptions be considered prudent? They find that commonly used actuarial tables for annuitants – as well as the Lee-Carter model – do not extrapolate life expectancy at the same rate for future years as for past years; instead they produce some longevity deceleration. This is typically because their mortality improvements decrease after a certain age, and those age-specific improvements are constant over time. As potential alternatives: (a) they study the Bongaarts model that produces straight increases in life expectancy; (b) they adapt it to produce best-practice longevity trends, (c) they compare with various longevity scenarios, including a model for ‘life extension velocity’, and (d) after gathering advances in bio-gerontology, they discuss issues to help retirement systems cope with a potential strong increase in life expectancy.

In ‘The Double-gap Life Expectancy Forecasting Model’, Marius Pascariu, Vladimir Canudas-Romo and James W. Vaupel show that life expectancy is highly correlated over time among countries and between males and females. These associations can be used to improve forecasts. The authors propose a method for forecasting female life expectancy based on analysis of the gap between female life expectancy in a country compared with the record level of female life expectancy in the world. Then, to forecast male life expectancy, the gap between male life expectancy and female life expectancy in a country is analysed. The authors present results for various developed countries and compare their results with forecasts based on the Lee-Carter and Cairns-Blake-Dowd models, focusing on forecasting life expectancy at age 0 and remaining life expectancy at age 65.

In ‘Mortality Models and Longevity Risk for Small Populations’, Jack C. Yue, Hsin Chung Wang and Chen-Tai Chong argue that prolonging life expectancy and improving mortality rates is a common trend of the 21st century. Stochastic models, such as the Lee-Carter model, are a popular choice to deal with longevity risk. However, these mortality models often have unsatisfactory results in the case of small populations. Thus, quite a few modifications (such as approximation and maximal likelihood estimation) to the Lee-Carter have to be used for the case of small populations or missing observations. In this study, the authors propose an alternative approach to improve the performance of stochastic models. The proposed approach is a combination of data aggregation and mortality graduation. The authors first combine the historical data of a target population, treating it as the reference population, and use data graduation methods (Whittaker and partial standard mortality ratio) to stabilize the mortality estimates of the target population. They first evaluate whether the proposed method have smaller errors in mortality estimation than the Lee-Carter model in the case of small populations, and explore if it is possible to reduce the bias of parameter estimates in the Lee-Carter model. They found that the proposed approach can improve the model fit of the Lee-Carter model when the population size is 200,000 or less.

In ‘Identifiability, Cointegration and the Gravity Model’, Andrew Hunt and David Blake point out that the gravity model of Dowd et al. (2011b) was introduced in order to achieve

coherent projections of mortality between two related populations. However, this model as originally formulated is not well-identified since it gives projections which depend on the arbitrary identifiability constraints imposed on the underlying mortality model when fitting it to data. In this paper, the authors discuss how the gravity model can be modified to give well-identified projections of mortality rates and how this result can be generalised to more complicated mortality models.

Finally, in 'Modeling Trend Processes in Parametric Mortality Models', Matthias Börger and Johannes Schupp argue that parametric mortality models like those of Lee and Carter (1992), Cairns et al. (2006b), or Plat (2009a) typically include one or more time-dependent parameters. Often, a random walk with drift is used to project these parameters into the future. However, longer time series of historical mortality data often show patterns which a random walk with drift is highly unlikely to generate. In fact, historical mortality trends often appear to be trend stationary around piecewise linear trends with changing slopes over time (see, e.g., Sweeting (2011) or Li et al. (2011)). Periods of lower mortality improvements are followed by periods of higher improvements and vice versa. In this paper, the authors propose an alternative trend process which builds on the patterns observed in the historical data. Future trend changes occur randomly over time, and also the trend change magnitude is stochastic. Furthermore, they show how the parameters of this trend process, in particular the probability of observing a trend change in a certain year and the distribution for the trend change magnitude, can be estimated from historical data. They also outline how uncertainty in the parameter estimates can be accounted for and compare the trend process to other trend processes which have been proposed in the literature.

Longevity 12 took place in Chicago on September 29–30, 2016. *Longevity 13* took place in Taipei, Taiwan on September 21–22, 2017. The *North American Actuarial Journal* will publish a Special Issue of selected papers presented at both conferences. *Longevity 14* will take place in Amsterdam on September 21–22, 2018 and *Longevity 15* will take place in New York on September 19-20, 2019.

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