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Mortality-Linked Securities and Derivatives

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MORTALITY-LINKED SECURITIES AND DERIVATIVES

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1. Introduction

In the last few years, the risk of mortality improvements has become increasingly capital intensive for pension funds and annuity providers to manage. The reason is that longevity risk has been systematically underestimated, making balance sheets vulnerable to unexpected increases in liabilities. The traditional way of transferring longevity risk is through insurance and reinsurance markets. However, these lack the capacity and liquidity to support an estimated global exposure in excess of $20tr (e.g., Loeys *et al.*, 2007). Capital markets, on the other hand, could play a very important role, offering additional capacity and liquidity to the market, leading in turn to more transparent and competitive pricing of longevity risk.

Blake and Burrows (2001) were the first to advocate the use of mortality-linked securities to transfer longevity risk to the capital markets. Their proposal has generated considerable attention in the last few years, and major investment banks and reinsurers are now actively innovating in this space (see Blake *et al.*, 2008, for an overview). Nevertheless, despite growing enthusiasm, longevity risk transfers have been materializing only slowly. One of the reasons is the huge imbalance in scale between existing exposures and willing hedge suppliers.[1] Another reason is that a traded mortality-linked security has to meet the different needs of hedgers (concerned with hedge effectiveness) and investors (concerned with liquidity and with receiving adequate compensation for assuming the risk), needs that are difficult to reconcile when longevity risk, a long-term trend risk that is difficult to quantify, is involved. Our aim is to provide an overview of the recent developments in capital markets aimed at overcoming such difficulties and at creating a liquid market in mortality-linked securities and derivatives.

Before outlining the contents of the chapter, we would like to give an idea of the magnitude of mortality improvements in recent years, by looking at UK experience in the period 1981-2005. As Figure 1 shows, the male life

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[1]The bulk of longevity exposures is represented by the liabilities of defined benefit pension funds and annuity providers. In 2007, these institutions' exposure to improvements in life expectancy amounted to a staggering $400bn in the UK and the US alone (see Loeys *et al.*, 2007).

expectancy at age 65 rose from 13 years in 1981 to almost 17 years in 2005. This corresponds to a rate of increase of more than 1% per annum. Female life expectancy rose from 17 to 19.7 years over the same period, corresponding to a 0.6% increase per annum. These increases in life expectancy are not a problem in themselves. They could be properly managed if the mortality improvements were fully anticipated. The real problem is that increases in life expectancy are surrounded by considerable uncertainty and changes in mortality rates are often unanticipated. This is what is meant when we refer to longevity risk as being a long-term trend risk.

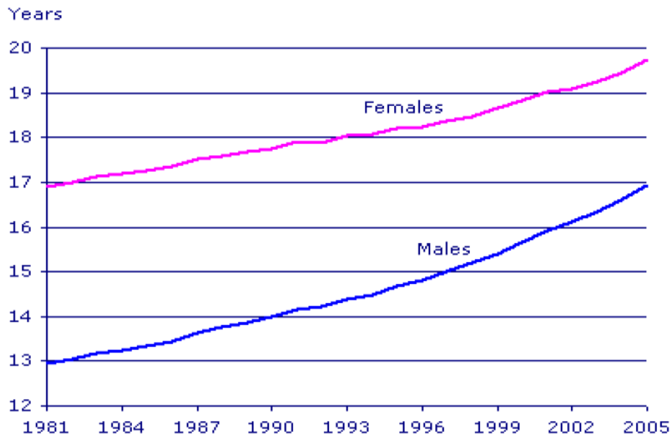

Figure 1: Life expectancy at age 65 in the UK, 1981-2005. Source: ONS (2007).

To understand the implications of longevity risk for pension plans and annuity providers, it is useful to look at a longevity fan chart, i.e. a plot depicting the increasing funnel of uncertainty around estimates of future life expectancy or, equivalently, around future mortality or survival rates. Figure 2 represents the forecast future life expectancies for 65-year-old English and Welsh males. The dark central band provides a 10% confidence level for the central estimate of the future life expectancy over the period 2000-2050. Surrounding the central band are bands of increasingly lighter shading, each representing additional 10% confidence intervals for the forecast range of life expectancies. The whole fan chart shows the 90% confidence interval for the life expectancy forecast. The best estimate forecast for life expectancy in 2050 is 26 years, a figure that lies between 21 and 32 years with 90% probability. Since every additional year of life expectancy at age 65 is estimated to add at least 3% to the present value of UK pension liabilities (e.g., PPF, 2006; Blake *et al.*, 2008), it is not difficult to see the economic implications of such a huge range of uncertainty. Similarly, if we adopt the perspective of an insurer willing to offer a pension plan protection against longevity risk (or of an investor willing to take on the longevity risk of a pension plan or annuity provider), it is not difficult to see why longevity risk hedges are very capital intensive and command high risk premia.

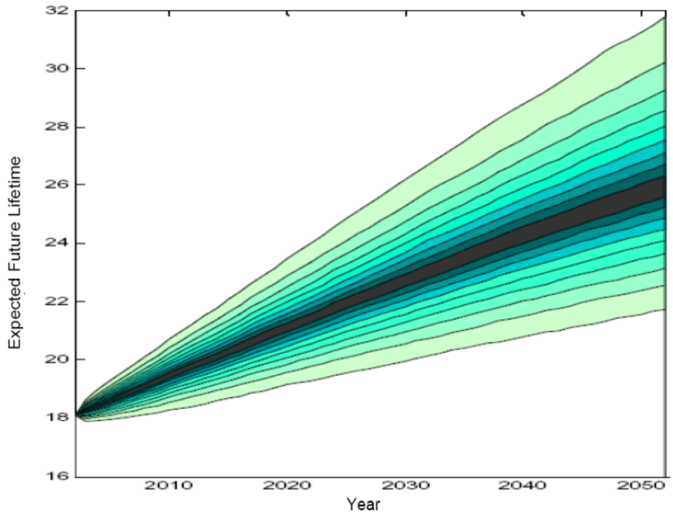

Figure 2: Longevity fan chart for 65-year-old English and Welsh males. Source: Dowd *et al.* (2007).

In the following sections, we offer an overview of the progress that has been made in less than a decade in developing a market in mortality-linked securities and derivatives. We begin in Section 2 with a description of the UK pension buyout market, and of the securitization of insurance assets and liabilities. Pension buyouts essentially involve transferring pension liabilities to an insurer, while securitizations involve capital markets investors, such as hedge funds, endowments, and ILS (insurance-linked securities) investors. In both cases, the longevity risk is typically transferred to a counterparty together with a number of other risks (e.g., inflation and interest rate risks). In Section 3, we look at examples of capital markets instruments providing exposure to pure longevity risk. We examine the structure of the first longevity bond offered to the market, and the reasons why it failed, as well as the structure of successful securities offering exposure to catastrophic mortality events.[2] In Section 4, we examine the most recent mortality-linked derivatives to appear on the market, namely derivatives with payoffs linked to a mortality index or to the mortality experience of a reference population. These include longevity swaps and mortality forwards. In Section 5, we examine the main advantages and disadvantages of the hedging solutions currently available in the market, classifying them into 'cashflow hedges' and 'value hedges'. We then examine the issues of longevity risk pricing and

[2]Although these securities involve risks that are the exact inverse of longevity risk, they represent the first examples of mortality-linked securities that have been actively traded.

the optimal design of mortality-linked securities and derivatives. Finally, Section 6 offers some concluding remarks.

2. Longevity risk transfers

The most direct way for a pension plan or an annuity provider to reduce its exposure to mortality improvements is to transfer part of its liabilities to a counterparty. The transfer may take the form of an insurance contract, in the case where the counterparty is a life insurer or reinsurer, or of a change of plan sponsor, in the case where the original employer's covenant is ended and the counterparty is another principal employer. An active pension buyout market has developed in the UK starting in 2006, enjoying formidable growth and attracting the participation of major players in financial markets. We outline the main features of this market in Section 2.1 below.

Much older than the pension buyout market is the traditional reinsurance market, which life insurers have long used to transfer part of their exposures, although the capacity of the reinsurance market to deal in longevity-linked exposures has generally been very limited. A new alternative to the reinsurance market is the transfer of risks to the capital markets via securitization of insurance assets and liabiliites. Investors have shown increasing interest in ILS as a way of diversifying their portfolios and earn extra returns that are uncorrelated with traditional equity and bond markets. We examine the most common forms of securitization in Section 2.2 below.

2.1. **Pension buyouts.** A common pension buyout transaction involves the transfer of a pension plan's assets and liabilities to a regulated[3] life insurer. A typical example is represented by a company with assets A and liabilities L, valued on an 'ongoing basis'[4] by the plan actuary. When the plan's assets are insufficient to cover the liabilities, i.e. $A < L$, the company recognizes a deficit of $L - A$. When $A > L$ instead, the company's plan has a surplus of $A - L$. Life insurers are usually required to value liabilities under more prudent assumptions (on future mortality improvements, inflation rates and market yields) than pension plans, resulting in a valuation $\widetilde{L} > L$ for the liabilities. This increases reported deficits or reduces reported surpluses when a company approaches an insurer for transferring its pension assets and liabilities.

In the case of a deficit, a company borrows the amount $\widetilde{L} - A$ and pays it to an insurer to buyout its pension assets and liabilities. The transaction allows the employer to off-load the pension liabilities from its balance sheet. This means that the volatility of assets and liabilities associated with the pension plan accounts, the payment of management fees on the plan's assets and any levies charged for members' protection plans[5] can be avoided. If buyout costs are financed by borrowing, a regular loan replaces pension assets and

[3] E.g., by the Financial Services Authority (FSA) in the UK.

[4] E.g., according to the pension accounting standard FRS17 in the UK.

[5] E.g., the Pension Protection Fund (PPF) in the UK.

liabilities on the balance sheet. From the point of view of the plan members, the pensions are secured in full, subject, of course, to the solvency of the life insurer.

There are alternative solutions to the full buy-out transaction we have just described. Partial buy-outs may take different forms, and involve the transfer of liabilities originating from a subgroup of members (e.g., deferred pensions, pensions in payment, etc.) or payable over a limited time-horizon (e.g, liabilities above 10 years maturity). These buyout deals are usually part of a broader ('de-risking') strategy for reducing the risk exposure of the pension plan or for tilting the investment strategy toward liability hedging (liability-driven investment (LDI)).

Buyout transactions have become increasingly popular in the UK in the last three years. Paternoster, run by Mark Wood, sealed the first buyout deal with the Cuthbert Heath Family plan in November 2006. A number of transactions followed, involving buyout startups as well as well known life insurers. In addition to Paternoster, companies active in the buyout space include Lucida (run by Jonathan Bloomer), Rothesay Life (owned by Goldman Sachs), the Pension Corporation (run by Eddie Truell, who secured the largest deal to date in the UK with the 1.1bn buyout of Thorn's pension fund), Canada Life, Aegon Scottish Equitable, Aviva and Axa among others. The reason for such interest in pension assets and liabilities is that insurers have superior expertise in forecasting and managing longevity-linked cashflows and can use the buyout transaction premium to set up a suitable hedging strategy as well as to earn a good return on capital employed. At the time of writing, the return on equity capital for the average buyout transaction is around 15%.[6] On the other hand, the pension buyout market has become so competitive that margins have reduced considerably. In addition, the new European solvency requirements for life insurers (Solvency II), due to be implemented by 2012, are likely to make the business increasingly capital intensive.[7] For these and other reasons, some new players have pursued the alternative route to the insured buyout and have opted for a change in the pension plan's sponsor, producing substantial savings on buy-out costs. An example of a so-called non-insured buyout is represented by Citigroup becoming the principal employer of Thomson Regional Newspapers' closed pension fund in August 2007.

2.2. **Securitization of life insurance assets and liabilities.** The interest in longevity-linked cashflows is not limited to pension liabilities and the pensions buyout market. Life insurance assets and liabilities have been attracting the attention of investors for at least two decades (e.g., Cowley and Cummins, 2005). The most common form of transaction involves the sale of a

[6]Communication of Jonathan Bloomer (Lucida) at the ILS Workshop held at Imperial College's Centre for Hedge Fund Research on October 31, 2008.
[7]"EU told to rethink rules on annuities", *Financial Times*, December 27, 2008.

pool of assets and liabilities (i.e., rights to a set of future cashflows) to a special purpose vehicle (SPV) and the repackaging of those assets and liabilities into securities traded in the capital markets. The SPV finances the purchase of assets and liabilities by issuing bonds to investors which are, in turn, secured against the assets and promised cashflows, possibly with some form of credit enhancement (e.g., overcollateralization, credit insurance, etc.).

The earliest and most common form of deals involves the securitization of the cashflows emerging from a block of business, such as a book of life policies. Life insurers are required to set up and maintain adequate reserves to meet liability payments when they fall due. As experience unfolds and liabilities are met, profits can be recognized on the balance sheet. Securitization give insurers the opportunity to convert to cash the future profits expected to emerge from a block of business.

A related form of life insurance securitization is regulatory reserving securitization, known as Triple-X securitization in the US.[8] Life insurance business is capital intensive, as the costs of writing new policies are incurred upfront, and the insurer needs to set up reserves that reflect the value of future liabilities under prudent assumptions. An insurer can 'release' the excess of reserves above the realistic valuation through securitization. The capital released can be used to support growth in the same or other lines of business. The key feature of Triple-X securitization is that the insurer's liabilities are not supported by the underlying assets but by the future premium receivables.

A more recent form of securitization involves the sale and repackaging of life settlement portfolios (see A.M. Best, 2008). These are portfolios of whole life policies that are sold by the owner to a third party, for a price that is higher than the cash surrender value, but lower than the net death benefit. The securitization of senior life settlements (i.e., policies issued to individuals aged 65+) began in 2004, with Tarrytown Second, a transaction involving \$63m of senior life settlements backed by \$195m life policies. In January 2005, the Life Exchange was established with a mission 'to provide the secondary life insurance market with the most advanced and independent electronic trading platform available by which to conduct life settlement transactions with the highest degree of efficiency, transparency, disclosure, and regulatory compliance'.[9] In April 2007, the Institutional Life Markets Association started in New York, as the trade body for the life settlements industry. In December 2007, Goldman Sachs launched a monthly index suitable for trading life settlements. The index, QxX.LS, is based on a pool of 46,290 anonymized lives aged 65+ from a database of life policy sellers assessed by the medical underwriter AVS.[10].

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[8]Triple-X regulation (see NAIC, 1999) applies to the valuation of life policies with guaranteed premiums over (part of) the policy term.

[9]See `www.life-exchange.com`

[10]See `www.qxx-index.com`

3. Capital market solutions and the development of mortality-linked securities and derivatives

As illustrated in the previous section, pension plans and annuity providers can sell their liabilities in the pension buyout market or transfer them to the capital markets via securitization. However, the cost of selling the longevity risk is bundled up with the cost of selling the other risks, making transactions more expensive and less transparent. Moreover, there are already signs of capacity constraints in the pension buyout market, as some of the insurers have been unable to attract additional shareholders' funds to expand their capital base. It is now recognzed that a greater involvement by the capital markets in managing longevity risk could increase the market capacity, increase liquidity, and allow a more transparent pricing of longevity risk. Blake and Burrows (2001) proposed the use of long-dated longevity bonds (or survivor bonds) to transfer the longevity risk to the capital markets. These are life annuity bonds with no return of principal and coupon payments declining in line with a chosen mortality index. Their proposal gave rise to a first generation of mortality linked securities characterized by a bond-like structure. We describe the most relevant examples below.

3.1. **The EIB longevity bond.**

The first attempt to issue a longevity bond was in November 2004 when BNP Paribas announced the issue by the European Investment Bank (EIB) of a 25-year bond with an issue price of £540m and coupons linked to a cohort survivor index based on the realized mortality rates of English and Welsh males aged 65 in 2002. The initial coupon was set equal to £50m, while the remaining coupons would have decreased in line with the mortality experienced by the reference cohort of male individuals. A representation of the security cashflows is provided in Figure 3 (see Blake *et al.*, 2006, for additional details). As the examples in Figure 4 show, the higher the number of survivors in the population each year, the higher the coupons paid to investors. Hence the instrument was mainly aimed at pension plans and annuity providers. However, the bond did not generate sufficient demand from investors to be actually launched, and was withdrawn for redesign in late 2005.

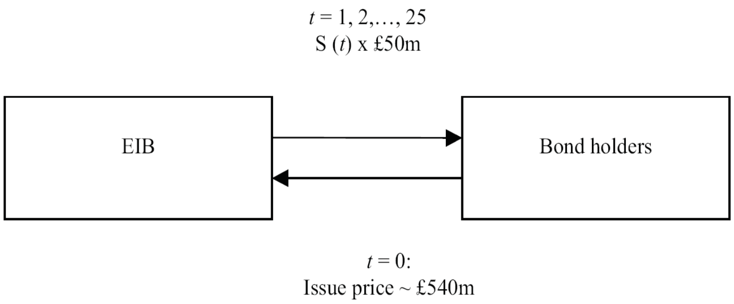

Figure 3: Cash flows from the EIB bond, as viewed by investors. $S(t)$ denotes the survivor index at the end of year t. Source: Blake *et al.* (2006).

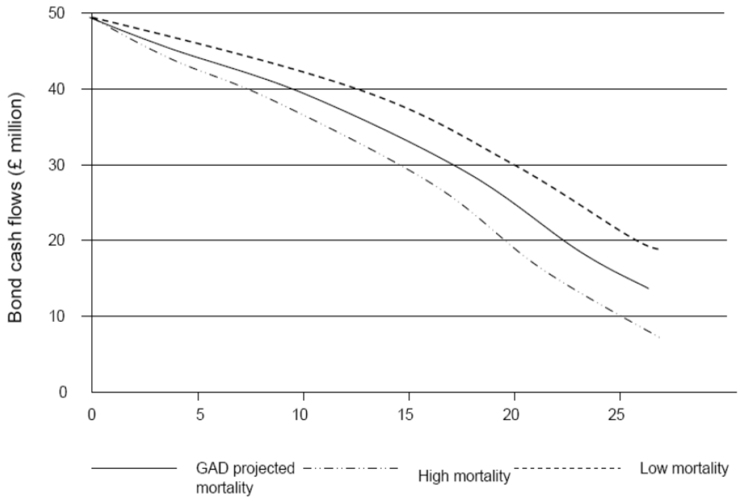

Figure 4: Coupons on the EIB bond. Source: Blake *et al.* (2006).

Despite its failure, the EIB longevity bond attracted considerable attention for the lessons that could be learned to improve the design and successfully develop a mortality-linked capital market. The main reasons why the EIB bond was poorly received by investors are as follows:

- *Basis risk*: The bond's mortality index covered just a fraction of the average pension plan's and annuity provider's exposure to longevity risk, which spans different cohorts of active and retired members. Furthermore, a large portion of pensions paid by pension funds and life insurers are indexed to inflation. Investors looking at the bond for hedging purposes were therefore concerned about both the considerable degree of basis risk arising from using an index based on a single birth cohort from the national population and the absence of an inflation hedge.
- *Capital strain*: As a hedging instrument, the structure of the EIB bond did not offer sufficient flexibility. A considerable upfront payment was required to access the longevity hedge component of the instrument, represented by a longevity swap which paid the longevity-linked coupons. The hedge was bundled up within a bond and provided no leverage opportunities. Furthermore, the size of the issue was too small to create a liquid market in the instrument.
- *Transparency*: The projected cashflows for the EIB bond (i.e., the fixed leg of the longevity swap) were based on projections prepared by the UK Government Actuary's Department (GAD), but the model used to make those forecasts is not published and the forecasts themselves are adjusted to reflect expert opinion in a way that is not made transparent. This represented a formidable barrier to investors not familiar with longevity risk and mortality projection models.

3.2. **Mortality catastrophe bonds.** Short-term mortality bonds are securities with payments linked to a mortality index. They are very similar to catastrophe bonds and have been successfully marketed in the last few years. The first mortality bond, known as Vita I, was issued by Swiss Re in December 2003 and was designed to reduce Swiss Re's own exposure to catastrophic mortality events, such as major terrorist attacks, avian flu pandemics, or other natural catastrophes. Vita I had a maturity of 3 years and an issue size of $400m. It was issued via an SPV, called Vita Capital, that invested the $400m principal in high-rated bonds, and swapped the bond income stream for LIBOR-linked cashflows. A scheme of the transaction is reported in Figure 5. Income was distributed to investors on a quarterly basis,[11] while the principal repayment at maturity depended on what happened to a particular index of mortality rates across different countries (US, UK, France, Italy, Switzerland) constructed to hedge Swiss Re's book of business. The principal was repayable in full if the mortality index did not exceed 1.3 times the 2002 base level during the mortality bond's life. Reduction in principal payments were 5% for each 1% increase in the mortality index above the base level, with exhaustion of principal at 1.5 times the base level (see Figure 6).

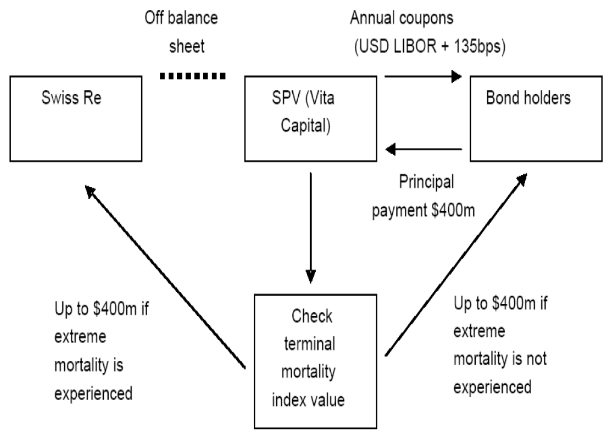

Figure 5: The structure of the Swiss Re bond. Source: Blake *et al.* (2006).

The issue of Vita I was very successful and was followed by a number of other bonds, such as: Vita II ($362m) in 2005 and Vita III ($705m) in 2007, again issued by Swiss Re; Tartan ($155m) in 2006, issued by Scottish Re; Osiris ($442m) in 2006, issued by AXA.[12] Investors find these securities attractive because they offer a high income relative to similarly rated floating rate instruments. It is worth noting that several pension funds figure among investors in mortality bonds. In addition to the appealing income stream,

[11]The bond was paying 135 basis points above LIBOR in November 2005.

[12]See Bauer and Kramer (2007) for an overview of recent transactions involving mortality catastrophe bonds.

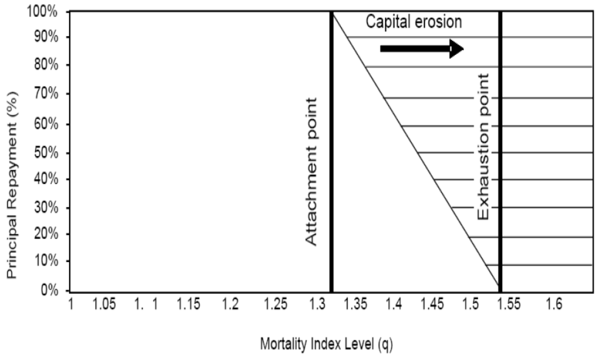

Figure 6: Principal-at-risk in the Swiss Re bond. Source: Blake *et al.* (2006).

they welcome the positive correlation of principal repayments with their active members and pensioners liabilities.

4. Recent trends in mortality-linked securities

The failure of the EIB longevity bond provided a number of insights into the right direction to follow to develop liquid mortality-linked securities and, especially, derivatives. Following the withdrawal of the EIB bond, major investment banks and reinsurers started to work on more transparent forms of mortality indexation and on more effective product designs, giving rise to a second generation of derivative-based products.

The shortcomings of the EIB bond provide a useful starting point for understanding the trends characterizing the latest developments in the market. The most important lesson to be learned from the EIB bond failure is that the survival of a traded capital market instrument depends on meeting the needs of both hedgers and speculators. While the former require an effective hedging instrument, the latter demand liquidity. Reconciliation of these different needs is not straightforward when longevity exposures are at stake, as we argue in the following sections and in Section 5.

4.1. **Mortality indices.** The single mortality benchmark underlying the EIB bond was considered inadequate to create an effective hedge by advisers and pension plan trustees. It soon became apparent that a flexible and reliable set of mortality indices was needed for contracts to be written on. A first attempt was made by Credit Suisse in 2005, with a Longevity Index developed for the US population life expectancy. The index suffered from similar transparency issues as the EIB bond's cohort index, and is no longer actively marketed by Credit Suisse.

A more successful attempt was made by JP Morgan, in conjunction with the Pensions Insitute and Watson Wyatt, with the launch of the LifeMetrics Indices in March 2007. The indices comprise publicly available mortality data at population level, broken down by age and gender, for different key countries (UK, US, Holland and Germany). To foster transparency of the indices and of mortality projection models, LifeMetrics include an open source toolkit for measuring and managing longevity risk and mortality projections.[13]

Finally, the Market Data & Analytics department of Deutsche Börse launched the Xpect-Indices in March 2008. Currently published for Germany and the Netherlands, these indices provide monthly estimates for the life expectancy of a reference group of individuals in a defined cohort or cohort group.

4.2. **Mortality swaps and forwards.** The derivatives products that are currently attracting the greatest attention from insurers and investment banks are mortality and longevity swaps. They involve counterparties swapping fixed payments for payments linked to the number of deaths (mortality swaps) or survivors (longevity or survivor swaps) in a reference population in a given time period. The derivative component of the EIB bond described in Section 3.1 is a longevity swap, since fixed payments from investors in the bond were intended to be swapped for coupons linked to the annual number of survivors in the cohort of English and Welsh males aged 65 in 2002. More generally, longevity swaps can diversify the exposure to longevity risk of a pension plan or annuity provider, by providing exposure to the mortality experience of different populations. For example, a US annuity provider could swap cashflows indexed on a US mortality index in exchange for cashflows based on a UK mortality index form a UK annuity provider counterparty. The first publicly announced longevity swap took place in April 2007: Swiss Re agreed to assume the longevity risk of £1.7bn pension annuity contracts written by Friends' Provident, a UK life assurer, in exchange for an undisclosed premium (see also Section 5.1).

A mortality swap can be synthesized by combining together several mortality forwards, i.e. contracts involving the exchange of a realized mortality rate relating to a specified population at a given future date, in exchange for a fixed mortality rate agreed at the beginning of the contract (this is called the forward rate). Contracts of this type have been marketed by JP Morgan since July 2007, under the name of q-forwards (see Coughlan *et al.*, 2007). They are believed to be good candidates to support the development of a liquid market in mortality derivatives, because they represent the building blocks of a number of more complex exposures. In addition, they have the potential to suit the hedging needs of parties that are net short longevity (pension plans and annuity providers) or net long longevity (providers of term assurances and whole life policies). Figure 7 presents a stylized diagram of a q-forward transaction, while Figure 8 provides an illustrative term sheet for a contract written on a reference population of 65-year-old English and Welsh men. The payoff from the q-forward depends on the value of the LifeMetrics index for the reference population on the maturity date of the contract. The contract involves JP Morgan providing a hedge to ABC

[13]See `www.lifemetrics.com`.

pension fund to cover its longevity risk (i.e., falls in mortality rates) over a 10 year horizon (2006-2016).

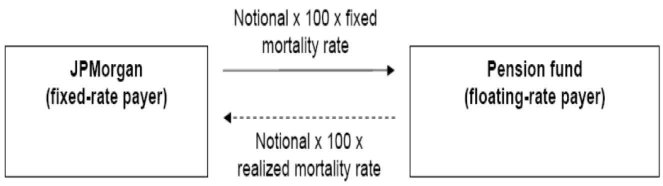

Figure 7: A q-forward exchanges fixed mortality for realized mortality at the maturity of the contract. Source: Coughlan *et al.* (2007).

Notional amount	GBP 50,000,000
Trade date	31 Dec 2006
Effective date	31 Dec 2006
Maturity date	31 Dec 2016
Reference year	2015
Fixed rate	1.2000%
Fixed amount payer	JPMorgan
Fixed amount	Notional Amount x Fixed Rate x 100
Reference rate	LifeMetrics graduated initial mortality rate for 65-year-old males in the reference year for England and Wales national population Bloomberg ticker: LMQMEW65 Index <GO>
Floating amount payer	ABC Pension Fund
Floating amount	Notional Amount x Reference Rate x 100
Settlement	Net settlement = Fixed amount – Floating amount

Figure 8: Illustrative term sheet for a single q-forward to hedge longevity risk. Source: Coughlan *et al.* (2007).

At maturity, the seller of longevity protection pays ABC Pension Fund an amount related to the forward mortality rate of 1.2%, in exchange for an amount related to the LifeMetrics reference rate that will be available at maturity. The settlement on 31 December 2016 will be based on the rate for the reference year 2015, given the 10-month lag in the availability of official data. The settlement amount is the difference between the fixed amount and the realized (floating) amount. Table 1 presents possible settlement amounts for different outcomes of the realized reference rate. If the realized mortality is lower than what was anticipated at the inception of the contract (i.e., the LifeMetrics rate for 2015 is lower than the forward rate), the settlement amount is positive and ABC Pension fund receives from JP Morgan an amount that can be used to offset its higher pension liabilities. If the realized mortality is higher than what was anticipated, it is the hedger who has to make a payment to JP Morgan, but this outflow is offset by a fall in its pension liabilities. The first trade in q-forwards took place in February 2008 between JP Morgan and the buyout firm Lucida (see Section 2.1).

Reference rate (Realized rate)	Fixed rate	Notional (GBP)	Settlement (GBP)
1.0000%	1.2000%	50,000,000	10,000,000
1.1000%	1.2000%	50,000,000	5,000,000
1.2000%	1.2000%	50,000,000	0
1.3000%	1.2000%	50,000,000	-5,000,000

Table 1: An illustration of q-forward settlement for various outcomes of the realized reference rate. Source: Coughlan *et al.* (2007).

4.3. **Mortality/longevity futures and options.** No futures or options markets on mortality-linked securities are active to date. However, considerable effort is being spent by reinsurers and investment banks to explore opportunities for innovation. In addition to the choice of underlying index, a key issue for options contracts is the choice of contract design (underlying, strike levels, tranches, etc.) to maximize liquidity. Some more details on these issues are provided in Section 5.3.

5. Hedging pension liabilities with mortality-linked securities and derivatives

In the previous sections, we highlighted the main features of those mortality-linked securities and derivatives that have appeared in the last few years. From what we have seen, it is clear that a major barrier to the development of a liquid mortality-linked capital market is represented by the different requirements of investors and holders of longevity exposures. We formalize these differences by classifying the hedging solutions currently available to pension plans and annuity providers under the headings of 'cashflow hedges' and 'value hedges' (see Sections 5.1-5.2).

We also examine the issue of longevity risk pricing and optimal security design. Although considerable progress has been made in understanding mortality dynamics (e.g., Dowd *et al.*, 2008a,b; Gourieroux and Monfort, 2008), the pricing of longevity risk remains elusive. The pricing exercises used so far by practitioners are typically based on partial equilibrium arguments (e.g., calibration of risk-neutral valuation models for annuity quotes or to assumptions used in reinsurance markets; see Bauer *et al.*, 2008) and shed little light on how supply and demand might equilibrate when longevity exposures are exchanged. We address this problem by describing the approaches of Loeys *et al.* (2007) and Biffis and Blake (2008) (see Section 5.3).

5.1. **Cashflow hedge paradigm.** Cashflow hedge solutions are similar to the traditional insurance paradigm, whereby the risk exposure is transferred to a counterparty which continues to pay the required cash flows. Contracts of this kind have the character of indemnification arrangements and typically make payments on a regular basis to cover the periodic liability outflows (e.g., the yearly annuity payments from a book of pension annuities). Examples of such hedges are represented by longevity swaps such as the Swiss Re - Friends' Provident longevity swap described in Section 4.2. The advantages of these contracts to the holder of longevity exposures are that the hedge entails no basis risk and, once set up, requires minimal monitoring. On the other hand, as customized hedges, they have some clear disadvantages. Since customized longevity risk solutions are complex and not very scalable or transferable, bespoke hedges involve higher set-up and operational costs. To minimize such costs, cash flow hedges are typically long-term and thus have greater exposure to counterparty credit risk. For these reasons, mortality-linked securities and derivatives based on customized hedges are unlikely to be attractive to capital market investors. This, in turn, reduces their liquidity and drives up the required longevity risk premium.

Despite the limitations and drawback we have highlighted, cashflow hedges seem to be the current preferred solution among pension plans trustees and annuity providers accustomed to the insurance indemnification paradigm. Financial intermediaries, such as investment banks, are actively attempting to enter this space. They offer to take on individual longevity exposures for later repackaging and reselling to capital market investors. One example of this is represented by a recent transaction involving JP Morgan and Canada Life, on the one side, and JP Morgan and the capital market investors, on the other side. The investment bank arranged a longevity swap with Canada Life and simultaneously executed a series of mirror swaps with the capital market investors seeking exposure to longevity risk for a suitable risk premium.

5.2. **Value hedge paradigm.** Value hedge solutions are common in capital markets. They are implemented by using standardized hedging instruments written on transparent indices. The payments are rolled up and paid on the maturity date, at which point they can be used to offset the liability outflows. The standardization and commoditization of these solutions means that they are much cheaper than customized hedges, and have the potential to appeal to a larger investor base, thus increasing liquidity and lowering risk premia. On the other hand, the standardization of value hedge instruments means that hedgers are likely to bear some basis risk.

Examples of these solutions are the q-forward contracts described in Section 4.2, and to some extent the EIB longevity bond examined Section 3.1. We saw that the structure of the EIB bond was too cumbersome to allow willing investors to exploit the value hedge potential of the longevity-linked coupons. The issue is resolved by mortality forwards, offering opportunities to leverage the exposure to a reference mortality index computed for a range of reference populations (different countries, ages, and gender) and time-horizons (e.g., 5, 10, and 15 years). Although the granularity and transparency of the indexing mechanism make mortality-forwards extremely flexible, the basis risk entailed by a standardized mortality index is still a major source of concern for pension plan trustees and annuity providers, exactly as it was in the case of the EIB longevity bond. Coughlan *et al.*

(2007) and Loeys *et al.* (2007) show that basis risk can actually be managed very effectively by writing derivatives based on the mortality experience of an entire age range in a given population ('age-bucketing'), since correlations between mortality improvements in the index and in the longevity exposures of typical hedgers increase dramatically. In addition to mitigating basis risk, the 'age-bucketing' concept streamlines the number of contracts necessary to meet the hedgers' needs and makes it easier to explain the advantages of value hedge solutions. Indeed, Coughlan *et al.* (2007) argue that a liquid, hedge-effective market could be built around just eight standardized q-forwards, with maturity (say) 10 years, broken down into two genders (male, female) and four age buckets (50-59,60-69,70-79,80-89). The first insurer to adopt a value hedge solution for its longevity exposure was Lucida, a pension buyout company. In January 2008 Lucida completed with JP Morgan a transaction in a mortality forward (i.e., a JP Morgan q-forward contract) written on the LifeMetrics index for England and Wales.

5.3. **Longevity risk pricing and optimal security design.** A key issue in the examples of the products covered above, in particular for the mortality derivatives described in Section 4.2 and 5.2, is the pricing of longevity risk in the absence of a liquid mortality-linked capital market. At the present time, there is no commonly accepted model for determining expectations about mortality improvements over time. Rather, there is a variety of competing mortality forecasting models available, each of which is subject to a considerable degree of estimation risk (see, e.g., Dowd *et al.*, 2008a,b; Cairns *et al.*, 2009).

As a reference point, Loeys *et al.* (2007) consider the historical volatility σ_q of the relative changes in mortality rates and the forecasts produced by the popular Lee-Carter model. Since longevity risk is virtually uncorrelated with other market risks, Loeys *et al.* (2007) argue that the required Sharpe ratio on q-forwards (see Section 4.2) should be lower than the one available for riskier asset classes such as equities, but high enough to attract investors to the market. They suggest an annualized Sharpe ratio of 25% as a possible benchmark. They then use the following expression to compute the forward rate q^{fwd} at which a q-forward contract such as the one described in Figure 8 should trade:

$$q^{\text{fwd}} = (1 - 0.25\ T\ \sigma_q)\, q^{\text{forecast}} < q^{\text{forecast}},$$

where T denotes the time to maturity (in years) of the forward contract and q^{forecast} is the best estimate for the future mortality rate. The above expression results in a forward rate lower than the expected mortality rate, as depicted in Figure 9. In other words, the party offering protection against longevity risk is paid a premium equal to Notional $\times$ $(q^{\text{forecast}} - q^{\text{fwd}}) \times 100$ by the hedger (see Figure 8). Loeys *et al.* (2007) show that the required risk premium can be reduced by averaging across age groups and time, since volatility in mortality data is affected by factors that are unsystematic to some extent (e.g., measurement error, cohort effects). As an example, they show that trading a mortality (q-) forward for the age range 70-79 in years 2015-2019 would generate a 40% reduction in the risk premium obtained for a forward on the mortality rate relative to age 75 in year 2017.

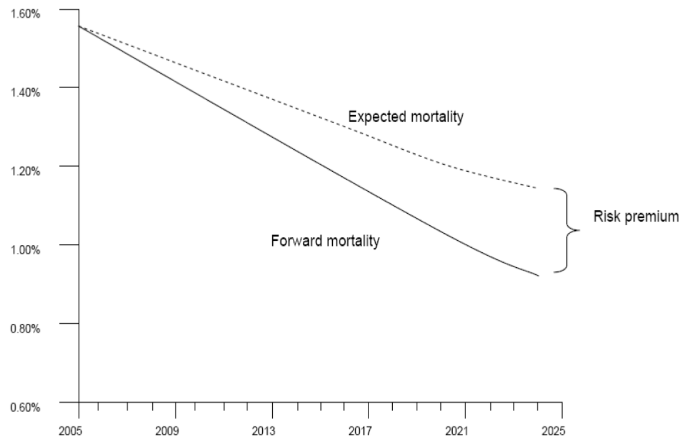

Figure 9: Expected and (illustrative) forward mortality rates for 65-year-old English and Welsh Male over 2005-2025. Source: adapted from Loeys *et al.* (2007).

The volatility of mortality rates is fairly low compared with the uncertainty surrounding changes in mortality trends. Forecasting mortality trends is a challenging exercise that concerns investors willing to take on exposures to longevity risk. Biffis and Blake (2008) explicitly distinguish the role played by trends and volatility in mortality rates in determining equilibrium risk premia in longevity risk transfers. Specifically, they model future mortality rates as

$$q(X) + \varepsilon, \tag{5.1}$$

where ε is an error term, while $q(X)$ represents a trend component that is affected by a vector of risk factors $X = (X^1, \dots, X^k)'$ or 'signals' (e.g., experience data, the outputs of stochastic mortality models, etc.). Biffis and Blake (2008) then consider markets populated by a large number of risk-neutral investors who have no access to the information carried by X, or are unskilled at providing a trend estimate $q(X)$ based on X. Investors currently still seem to be uncomfortable enough with longevity risk to make this a plausible situation, even for securities written on publicly available demographic indices. At the other end of the spectrum, there are holders of longevity exposures that have access to X (in terms of better experience data or forecasting technologies developed by monitoring the exposures). This situation is realistic for life insurers, reinsurers and other intermediaries (e.g., pension buyout firms and investment banks) that have developed considerable expertise in managing mortality-linked cashflows. The incentive to enter a transaction and transfer the longevity exposure to the capital markets is given by an exogenously specified retention cost resulting from capital requirements or alternative investment opportunities. Knowledge of this cost is available to all agents and it can be quantified from international regulatory rules and accounting standards.

Biffis and Blake (2008) first focus on the securitization market and show how the informational asymmetry regarding the trend component of longevity risk results in a downward sloping market demand for longevity exposures. Consider the securitization of a book of annuity-like cashflows and their backing assets. The presence of asymmetric information means that the holder or originator of the longevity exposure faces a 'lemons' problem (as in Akerlof, 1970), because investors do not have access to the private signal X. As is common in annuity reinsurance and the securitization of insurance assets and liabilities (see Section 2.2 and Cowley and Cummins, 2005), retention of part of the exposure can be used to 'prove' the quality of the cashflows to the market and alleviate the impact of asymmetric information. Biffis and Blake (2008) use a signalling model of market equilibrium as in DeMarzo and Duffie (1999) to determine the optimal retention and securitization levels. As a particular example, consider the situation where a riskless asset valued at $\alpha \geq 0$ backs a promised payment that depends on the proportion of survivors in a given population at some future date T, say S. Figure 10 shows that the optimal securitized fraction of the net exposure $\alpha - S$ is increasing in the trend component $q(X)$, i.e. in the private valuation of longevity risk (see the right-hand vertical axis in Figure 10). The reason is that a lower private valuation $q(X)$ makes the cashflow $\alpha - S$ relatively less valuable and hence securitization relatively more valuable. On the other hand, investors rationally anticipate that the amount of exposure put up for sale is increasing in the private valuation of longevity risk, and the price they are willing to pay for the exposure is decreasing in the securitizated fraction, leading to a lower securitization payoff (see the left-hand vertical axis in Figure 10).

Biffis and Blake (2008) then allow the holder of the book of liabilities and backing assets to issue a security that is contingent on the net exposure $\alpha - S$ and examine conditions under which the optimal contract results in tranching of the net exposure. By tranching, they mean slicing the net exposure so that, in exchange for a lump sum paid to the originator, investors who buy the tranche put up for sale are entitled to a specific portion of the net exposure's cashflows. The optimal tranching level minimizes the sensitivity of these cashflows to both asymmetric information and the impact of unsystematic risk, both of which are material to risk-neutral agents when payoffs are nonlinear. The optimal tranche is the one that is least risky from the investors' viewpoint, and is equivalent to the senior debt tranche in a debt financing operation.

Biffis and Blake (2008) extend their analysis to the market for mortality-linked derivatives and examine the issue of optimal contract design under asymmetric information about mortality trends. Under reasonable assumptions about the components $q(X)$ and ε, they find that the optimal securities are put options on mortality rates sold by investors to hedgers wishing to cap their exposure to longevity risk. More interestingly, Biffis and Blake

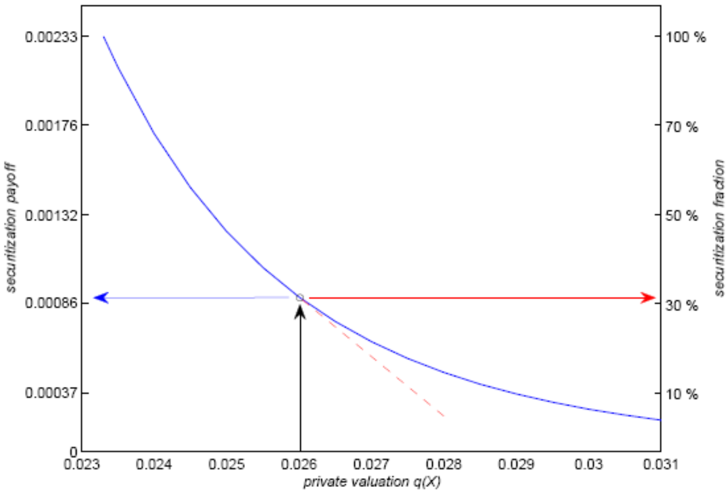

Figure 10: Securitization payoff and securitization fraction as a function of the private valuation $q(X)$ of the trend component of longevity risk. The plot is based on the death rate of a UK male aged 75 in year 2009. Source: Biffis and Blake (2008).

(2008) determine the optimal strike levels for such options. The optimal strikes can be interpreted as mortality rates at which the marginal benefit to the hedger from purchasing additional protection from the capital market investors is equal to the marginal retention cost of the exposure. By analogy with the analysis of Loeys *et al.* (2007), Biffis and Blake (2008) show that hedging costs can be reduced by writing derivatives on exposures pooled across age ranges or time periods. More precisely, diversification benefits can be traded off against the detrimental effect of information loss from pooling together low-longevity- and high-longevity-risk cashflows. Biffis and Blake (2008) show that pooling and then tranching longevity exposures can reduce the negative impact of unsystematic longevity risk that is particularly prevalent at high ages and in small portfolios. Also, the benefits from pooling and tranching are magnified when the information on mortality trends is highly correlated across exposures, while residual risk is not. This occurs, for example, when issuers of securities pool different cohorts of individuals belonging to the same geographic area or social class, or pool several small portfolios with similar demographic characteristics. When considering securities written on publicly available demographic indices, the model shows that 'age-bucketing' can reduce asymmetric information costs in addition to mitigating basis risk (see Section 5.2).

6. Conclusion

In this chapter, we have reviewed the main drivers behind the branch of financial innovation that focuses on capital market solutions for managing longevity risk. This new and exciting field has seen major reinsurers and investment banks spending considerable resources in an attempt to develop solutions that successfully bring together both hedgers and capital market investors. Substantial progress has been made in product design and some key transactions have taken place. The next few years will show which mortality-linked financial securities and derivatives will provide a valid alternative to the more traditional insurance solutions and offer new capacity for the transfer of longevity risk exposures.

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