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Longevity Risk and Capital Markets: The 2013-14 Update

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Longevity Risk and Capital Markets: The 2013-14 Update

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This Special Issue of *Insurance: Mathematics and Economics* contains 14 contributions to the academic literature all dealing with longevity risk and capital markets. Draft versions of the papers were presented at *L9: The Ninth International Longevity Risk and Capital Markets Solutions Conference* that was held in Beijing, China on 6-7 September 2013. It was hosted by the China Institute for Actuarial Science (CIAS), Central University of Finance & Economics (CUFE) and co-hosted by: the China Association of Actuaries; the Waterloo Research Institute in Insurance, Securities and Quantitative Finance (WatRISQ), University of Waterloo, Canada; the Edmondson-Miller Chair, Illinois State University, USA; the Pensions Institute, Cass Business School, City University London, UK; and the Risk Management and Insurance Department, National Cheng-Chi University, Taiwan. It was sponsored by Société Générale Corporate and Investment Banking, the Institute and Faculty of Actuaries, SCOR Global Life, Hannover Re, Risk Management Solutions (RMS), the Society of Actuaries (SOA), and Cathay Life Insurance

Longevity risk and related capital market solutions have grown increasingly important in recent years, both in academic research and in the markets we refer to as the 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 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.

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[1] Blake et al. (2013)

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 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. 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.[3] 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.[4] 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 (www.lifemetrics.com); the world's first publicly announced longevity swap between Swiss Re and the UK life office Friends' Provident in April 2007 (although this was structured as an insurance or indemnification contract rather than a capital market transaction).

[2] The conference proceedings for *L2* were published in the December 2006 issue of the *Journal of Risk and Insurance*.
[3] The conference proceedings for *L3* were published in the Fall 2008 issue of the *Asia-Pacific Journal of Risk and Insurance*.
[4] In fact, Asia has the world's largest and fastest growing ageing population (United Nations, 2007).

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.[5] 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.[6]

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[7] 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. Twenty nine longevity swaps were completed in the United Kingdom between 2007 and 2014, valued at £55bn and covering 10 insurance companies' annuity books, 12 private sector pension funds, and one local authority pension fund (some of which executed more than one swap). 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 Pension Scheme, arranged by the Prudential Insurance Co of America in July 2014. In February 2010, Mercer launched a pension buyout 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.[8] In 2008, Credit Suisse initiated a longevity swap with Centurion Fund Managers, whereby Centurion acquired a portfolio of synthetic

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[5] 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.

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

[7] Coughlan et al. (2007).

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

(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.[9] On 1 February 2010, the Life and Longevity Markets Association (LLMA) was established in London. Its current members are Aviva, AXA, Deutsche Bank, J.P. Morgan, Legal & General, Morgan Stanley, Munich Re, Pension Corporation, Prudential PLC, RBS 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.[10] In December 2010, building on its successful mortality catastrophe bonds and taking into account the lessons learned from the EIB bond, Swiss Re launched a series of eight-year longevity-based ILS notes valued at $50 million. 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

[9] The conference proceedings for *L5* were published in the *North American Actuarial Journal* (Volume 15, Number 2, 2011).
[10] The conference proceedings for *L6* were published in the October 2011 issue of *Geneva Papers on Risk and Insurance - Issues and Practice.*

risk: there is no cash flow risk and most of the risk lies in the forecasts of mortality improvements. Further, the longevity exposure of deferreds is not well defined as a result of the options that plan members have, e.g., lump sum commutation options, early retirement options, and the options to increase spouses' benefits at the expense of members' benefits.

In April 2011, the International Society of Life Settlement Professionals (ISLSP)[11] 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 (i.e., bulk annuity purchase to hedge the longevity risk of pensions in payment) outside the UK took place in 2009 in Canada; it was arranged by Sun Life Financial and valued at C$50 million. The first buy-in deal in Europe took place in December 2010 between the Dutch food manufacturer Hero and the Dutch insurer Aegon (€44 million). The first buy-in deal in the US took place in May 2011 between Hickory Springs Manufacturing Company and Prudential (US) ($75 million). 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 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.[12]

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

[11] www.islsp.org

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

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 December 1, 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.[13] 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 eighth conference *(L8)* was held at the University of Waterloo, Ontario, Canada on 7-8 September 2012.[14]

In February 2013, the first medically underwritten bulk annuity transaction was executed in the UK by the UK insurer Partnership.[15] 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 the largest medically underwritten bulk annuity transaction to date with a £206 million "top slicing" arrangement for an unnamed multi-billion pound pension fund.

In April 2013, Legal & General reported its first non-UK deal, the buy-out of a €136 million annuity book from New Ireland Life. The following month, L&G announced that it was entering the Dutch pension fund buy-out market which had a total potential value of €800 billion in May 2013. In June 2013, the Canadian Wheat Board executed a C$150 million pension buy-in from Sun Life of Canada, involving inflation-linked annuities, while in March 2014, an unnamed Canadian company purchased C$500 million of annuities from an insurer reported to be Industrial Alliance, making it the largest ever Canadian pension risk transfer deal to date.

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[13] In fact, the lump sum is only being offered to limited cohorts of plan members.
[14] The conference proceedings for *L8* were published in the *North American Actuarial Journal* (Volume 18(1), 2014).
[15] Harrison and Blake (2013).

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

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 Life and Longevity Markets Association longevity indices. LEOs will be traded over-the-counter under a standard ISDA 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.

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

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 £100 million of pension liabilities was 123% of the accounting value of the liabilities. The comparable costs in Ireland, the U.S. and Canada were 117%, 108.5% and 105%, respectively. The higher cost in the UK is in part due to the greater degree of inflation uprating in the UK compared with the other countries. The difference between the US and Canada is explained by the use of different mortality tables. Rising interest rates and equity markets will lower funding deficits and hence lead to lower buy-out costs in future, especially in the US.

In 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 standardised processes for quantifying the longevity risk in each pension scheme. In December 2014, Towers Watson launched Longevity Direct, an off-shore longevity swap hedging service that gives medium-sized pension schemes with liabilities between £1-3bn direct access to the reinsurance market, via its own cell 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 collateralised and each scheme owns a cell within Iccaria which again avoids the costs of dealing with insurer and investment bank intermediaries.

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. For example, in 2014, Warren Buffett's Berkshire Hathaway agreed to a £780 million quota-reinsurance deal with the Pension Corporation, a specialist UK buy-out insurer.[16] In March 2014, the UK insurer Legal & General announced the biggest single buy-out in the UK to date when it took on £3bn of assets and liabilities from ICI's pension fund, a subsidiary of AkzoNobel. In December 2014, Legal & General announced the largest ever UK buy-in valued at £2.5bn with US manufacturer TRW. More than £10bn 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. In August 2014, Legal & General reported that it was expanding its pension buy-out and buy-in business in Europe and North America. 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, such as Friends Life and Scottish Widows, are considering entering the bulk annuity market.

In November 2014, the Longevity Basis Risk Working Group (LBRWG) of the Institute & Faculty of Actuaries (IFoA) and the Life and Longevity Markets Association (LLMA) published "Longevity Basis Risk: A Methodology for Assessing Basis Risk". This study

[16] Reported in *Financial News*, 14 July 2014.

develops a new framework for insurers and pension schemes to assess longevity basis risk. This, in turn, will enable simpler, more standardised 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 scheme. The methodology developed in the report is applicable to both large schemes (which are able to use their own data in their models) and smaller schemes (by capturing demographic differences such as socio-economic class and deprivation).

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)).
- 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)), survivor/longevity forwards and swaptions (e.g., Dawson et al. (2010)), *q*-forwards (e.g., Deng et. al. (2012), Barrieu and Veraart (forthcoming)) and mortality options (e.g., Milevsky and Promislow (2001))
- 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 of life settlements (e.g., Deng et al. (2011), Brockett et al. (2013), Zhu and Bauer (2013))
- Longevity and mortality indices (e.g., Denuit (2009), Li et al. (2011), Chan 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))
- 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), Cairns (2013), Cox et al. (2013a,b), Qiao and Sherris (2013), Cairns et al. (2014), Zelenko (2014), Zhu and Bauer (2014))

- Mortality modeling, mortality term structure[17] modelling, and mortality forecasting (e.g., Booth et al. (2002a,b), Brouhns et al. (2002a,b), 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. (2008), 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), Lin and Tzeng (2010), Murphy (2010), Yang et al. (2010), Coelho and Nunes (2011), D'Amato et al. (2011), Gaille and Sherris (2011), Hanewald (2011), Li and Chan (2011), Milidonis et al. (2011), Russo 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), O'Hare and Li (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), Berkum et al. (forthcoming), Currie (forthcoming))
- 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))
- 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))
- Longevity risk in investment portfolios (e.g., Milevsky and Young (2007), Menoncin (2008), Horner et al. (2008, 2009, 2010), Horneff et al. (2010), Huang et al. (2012), Maurer et al. (2013))
- Longevity risk in pension plans and pension systems (e.g., Aro (2014), Bisetti and Favero (2014), Lin et al. (2014)).

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.[18] The life settlements market has been dogged by systematic

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

[18] 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

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.

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 Legal & General 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.

As with the previous conferences, *L9* consisted of both academic papers and more practical and policy-oriented presentations. The conference was addressed by the following keynote speakers:

- Professor Shripad (Tulja) Tuljapurkar (Dean and Virginia Morrison Professor of Population Studies, Stanford University) gave a presentation on "How and why mortality change varies between sexes and countries". His key findings (which are broadly common to all developed countries) are: mortality declines at every age contribute to narrowing the female–male gap in life expectancies; smoking differences (men now smoke less than women in a number of countries) are *cohort*

less important than systematic mortality risk which is essentially the trend risk of getting life expectancy projections wrong.

effects, but lung cancer (and hence smoking) are only a small component of death rates; and ischemic heart disease deaths (vastly more deaths than lung cancer) are falling rapidly in men and this is a *period effect*. The combined effect is that over time men's mortality rates are becoming more like women's.

- The presentation by Pablo Antolin (Principal Economist, Financial Affairs Division, OECD) entitled "Mortality assumptions and longevity risk" discussed the findings of a major OECD study on assessing the longevity risk in pension funds and annuity providers in a number of OECD and non-OECD countries. The aim of the study was to measure the potential exposure to longevity risk by comparing the life expectancy and annuity premiums implied from using the mortality tables employed by regulators and market participants in the countries considered with life expectancy and annuity premiums derived from the OECD's own mortality model projections. The OECD's analysis shows that pension funds and annuity providers inadequately provision for future improvements in mortality, although the mortality tables used by insurance companies selling annuities account for future mortality improvements in more countries than those used by pension funds.
- Cord-Roland Rinke (Managing Director, Hannover Life Re) gave a presentation entitled "Enhanced annuities in Asia: a case study". People with severe diseases are disadvantaged if they buy a standard life annuity. This led to the development of enhanced annuities which make higher annuity payments to applicants with reduced life expectancy due to lifestyle or diseases. The enhanced annuity market began in the UK when the first smoker annuity was introduced in 1995 and reached 41% of the total annuity market by 2011. The presentation considered whether the concept of enhanced annuities was transferable to Singapore, a country with substantial savings at retirement and mandatory annuitization of a minimum fund size.
- Professor Zheng Bingwen (Director General of the Center for International Social Security Studies (CISS) at the Chinese Academy of Social Sciences (CASS)) gave a presentation entitled "China's three-pillar pension system: facing the challenge of longevity risk".
- Professor Xiaolin Li (China Institute for Actuarial Science, CUFE) chaired a panel discussion entitled "Longevity issues in Asia: challenges and opportunities". The panellists were Yu Cai (Director, Policy and Research Department, China Insurance Regulatory Commission), Meipan Tian (Chief Actuary, China Re Group), Professor Jennifer Wang (Vice Chairperson, Financial Supervisory Commission and Distinguished Professor of National Cheng-Chi University, Taiwan), Chun-Hung Wu (Senior Vice President, Cathay Life Insurance Co.), and Professor Bingwen Zheng.
- Tonya Manning (President, Society of Actuaries) gave a presentation entitled "The role of the Actuarial Profession in addressing longevity risk". She saw the key roles of actuaries as: measuring and managing longevity risk for providers of life insurance, annuities, pensions and long-term care; and helping to ensure the solvency of annuity, pension and social insurance systems. This required dealing with five challenges: recognising that longevity risk is important and that this risk is systemic, rather than idiosyncratic; history shows steady longevity improvement; the need to take into account improvement in mortality rates going forward;

improvement rates are not uniform across populations; and modelling is imperfect and needs to be a combination of science, art, and educated guess. The SOA Longevity Task Force was established in 2012 and was charged to consider: what actions the SOA should take in response to the rapidly changing science; and how can the SOA be more proactive in serving the needs of key stakeholders (members, public, policy-makers, regulators). The task force set four recommended goals: SOA members recognize the impact of changing longevity as a key risk to be managed; SOA members play a public leadership role in longevity impact risk management; the SOA supports actuaries so that they can be leading experts on longevity risk management; and SOA members and volunteers recognize the expertise of others in longevity and use that expertise.

- Daria Ossipova-Kachakhidze (Head of Longevity and Mortality R&D, SCOR) gave a presentation entitled "Reinsurance of longevity: risk transfer and capital management solutions". She considered the advantages and disadvantages of both insurance and capital markets based solutions for transferring longevity risk.
- Guy Coughlan (Managing Director, Pacific Global Advisors) chaired a panel discussion entitled "Accelerating the development of a liquid risk transfer market for longevity". The panellists were Jeff Mulholland (Managing Director and Head of Insurance and Pension Solutions in the Americas, Société Générale), Chris Madsen (Head of Risk Structuring and Transfer, Aegon NV), Chris Hornsby (Longevity Risk Model Manager, RMS LifeRisks), Andrew Coburn (Senior Vice President, RMS LifeRisks) and Peter Schliebs (Challenger Life Company Limited). The panel discussed the €1.4 billion Aegon longevity risk transfer which was formally announced in December 2013. Madsen discussed the transaction from the sponsor perspective, Mulholland discussed it from the investment banking perspective, Hornsby and Coburn from the modelling perspective, and Schliebs from the investor perspective. The panel also discussed the lessons learned and how these lessons could help promote more and larger transactions in future.
- David Hare (President, Institute and Faculty of Actuaries) was the keynote speaker at the Gala Dinner and gave a talk entitled "The Challenges for Actuaries in Dealing with Longevity Predictions".

The conference papers reviewed and selected for publication in this Special Issue cover the following themes: longevity bonds and survivor swaps, longevity risk measurement and de-risking in defined benefit pension plans, reverse mortgage pricing, variable annuities and guaranteed annuity options, multi-population mortality models, mortality forecasting, heterogeneity in prospective mortality tables, and mortality dependence between individuals in a couple. We briefly discuss each of the 14 papers selected.

In "Modelling Longevity Bonds: Analysing the Swiss Re Kortis Bond", Andrew Hunt and David Blake argue that a key contribution to the development of the traded market for longevity risk was the issuance of the Kortis bond, the first longevity trend bond, by Swiss Re in 2010. This paper analyses the design of the Kortis bond, develops suitable mortality models to analyse its payoff and discusses the key risk factors for the bond. It also investigates how the design of the Kortis bond can be adapted and extended to further develop the market for longevity risk.

In “Modeling Multi-Country Mortality Dependence and Its Application in Pricing Survivor Index Swaps—A Dynamic Copula Approach”, Chou-Wen Wang, Sharon S. Yang and Hong-Chih Huang introduce mortality dependence in multi-country mortality modelling using a dynamic copula approach. Specifically, they use time-varying copula models to capture the mortality dependence structure across countries, examining both symmetric and asymmetric dependence structures. In addition, to capture the phenomenon of a heavy tail for the multi-country mortality index, the authors consider not only the setting of Gaussian innovations but also non-Gaussian innovations under the Lee-Carter framework model. As tests of the goodness of fit of different dynamic copula models, the pattern of mortality dependence, and the distribution of the innovations, the study uses empirical mortality data from Finland, France, the Netherlands, and Sweden. To understand the effect of mortality dependence on longevity derivatives, the authors also build a valuation framework for pricing a survivor index swap and investigate the fair swap rates of a survivor swap numerically. They demonstrate that failing to consider the dynamic copula mortality model and non-Gaussian innovations would lead to serious underestimations of the swap rates and loss reserves.

In “A New Defined Benefit Pension Risk Measurement Methodology”, Jing Ai, Patrick L. Brockett and Allen F. Jacobson argue that defined benefit pension plan sponsors have taken on greater risks for sponsoring these plans in the last several years. Due to ever increasing concerns about longevity risk and the weak economic environment, sponsors are eager to understand their pension-related risks to facilitate optimal enterprise decision-making. Borrowing an analytical framework from the life insurance and annuity industry where the amount of risk is framed in terms of the total assets required to remain solvent over a one-year period with a high level of confidence, i.e., the economic capital approach, this paper develops a benchmark risk measure for pension sponsors by obtaining a total asset requirement for sustaining the pension plan. The difference between the total asset requirement and the actual trust assets thus provides a measure of sponsor assets at risk due to plan sponsorship. Two factor-based approaches are proposed for this calculation. The first approach develops a set of pension-specific factors as if the pension plan were a group annuity. The second approach directly simulates the risk drivers of the pension plan and develops a framework for obtaining factors and calculating the pension risk given a desired confidence level. The approach is very easy to implement and monitor in practice.

In “De-Risking Defined Benefit Plans”, Yijia Lin, Richard D. MacMinn and Ruilin Tian wish to identify an appropriate pension de-risking method and propose an optimization model that minimizes the expected total pension cost subject to a conditional value at risk (CVaR) constraint on the pension funding level. Using this model, the authors examine three pension hedging strategies, namely a longevity hedge, a buy-in and a buyout. Each strategy is examined for hedging costs that include a risk premium, a search and information cost, an underfunding cost, and a counter-party risk cost. The numerical examples used in the paper demonstrate that these hedging costs have a significant impact on the hedging decision. The hedge ratio (total pension cost) decreases (increases) with the transaction cost, the counter-party default probability and the underfunding ratio.

In addition, the buy-out underperforms both the longevity hedge and the buy-in for underfunded plans and the longevity hedge is less sensitive to the default risk than the buy-in.

In "Swiss Coherent Mortality Model as a Basis for Developing Longevity De-Risking Solutions For Swiss Pension Funds: A Practical Approach", Cheng Wan and Ljudmila Bertschi show that pension funds in Switzerland are exposed to longevity risk possibly to a greater extent than in many other developed economies. The reason for this is a dearth of financial products to combat longevity risk, with a lack of buy-in and very limited variety of buy-out solutions available. The solutions that do exist frequently come at a very high price and many pension funds are in deficit on a buy-out basis. The authors argue that creating an approach to evaluating the longevity risk faced by each pension fund and integrating it into dynamic risk budgeting strategies will help Swiss pension funds better understand the mechanisms underlying different longevity de-risking solutions and help them decide on the most suitable as well as most affordable solution for them. For developing capital market solutions for longevity hedging strategies, it is crucial that both hedgers (pension funds) as well as solution providers are able to quantify the longevity risk in a holistic risk management framework and to develop a suitable pricing approach.

In **"**Reverse Mortgage Pricing and Risk Analysis Allowing for Idiosyncratic House Price Risk and Longevity Risk", Adam W. Shao, Katja Hanewald and Michael Sherris show that reverse mortgages provide an alternative source of funding for retirement income and health care costs. The two main risks that reverse mortgage providers face are house price risk and longevity risk. Recent real estate literature has shown that the idiosyncratic component of house price risk is large. They analyse the combined impact of house price risk and longevity risk on the pricing and risk profile of reverse mortgage loans in a stochastic multi-period model. The model incorporates a new hybrid hedonic-repeat-sales pricing model for houses with specific characteristics, as well as a stochastic mortality model for mortality improvements along the cohort direction (the Wills-Sherris model). Their results show that pricing based on an aggregate house price index does not accurately assess the risks underwritten by reverse mortgage lenders, and that failing to take into account cohort trends in mortality improvements substantially underestimates the longevity risk involved in reverse mortgage loans.

In "Optimal Life Cycle Portfolio Choice with Variable Annuities Offering Liquidity and Investment Downside Protection", Vanya Horneff, Raimond Maurer, Olivia S. Mitchell, and Ralph Rogalla assess optimal life cycle consumption and portfolio allocations when households have access to Guaranteed Minimum Withdrawal Benefit (GMWB) variable annuities over their adult lifetimes. The paper evaluates the demand for these products which provide access to equity investments with money-back guarantees, longevity risk hedging, and partially-refundable premiums, in a realistic world with uncertain labor and capital market income as well as mortality risk. Others have predicted that consumers will only purchase such annuities late in life, but the authors show that they will optimally purchase GMWBs prior to retirement. Additionally, many individuals optimally adjust their portfolios and consumption streams along the way by taking cash withdrawals from these products. The products can substantially enhance consumption, by up to 10% for those who have highly unfavorable experiences in the stock market.

In “Mortality Modelling With Regime-Switching For the Valuation of a Guaranteed Annuity Option”, Huan Gao, Rogemar Mamon, Xiaoming Liu and Anton Tenyakov consider three ways of putting forward a regime-switching approach to modelling the evolution of mortality rates for the purpose of pricing a guaranteed annuity option (GAO). This involves the extension of Gompertz and non-mean reverting models as well as the adoption of a pure Markov model for the force of mortality. A continuous-time finite-state Markov chain is employed to describe the evolution of mortality model parameters which are then estimated using the filtered-based and least-squares methods. The adequacy of the regime-switching Gompertz model for US mortality data is demonstrated via the goodness-of-fit metrics and likelihood-based selection criteria. A GAO is valued assuming the interest and mortality risk factors are switching regimes in accordance with the dynamics of two independent Markov chains. To obtain closed-form valuation formulae, the authors employ the change of measure technique with the pure endowment price as the numéraire. Numerical implementations are included to compare the results of the proposed approaches and those from the Monte Carlo simulations.

In “A Step-by-Step Guide to Building Two-Population Stochastic Mortality Models”, Johnny Siu-Hang Li, Rui Zhou and Mary Hardy show that two-population stochastic mortality models play a crucial role in the securitization of longevity risk. In particular, they allow the quantification of population basis risk when longevity hedges are built from broad-based mortality indexes. In this paper, the authors propose and illustrate a systematic process for constructing a two-population mortality model for a pair of populations. The process encompasses four steps, namely (1) determining the conditions for biological reasonableness, (2) identifying an appropriate base model specification, (3) choosing a suitable time-series process and correlation structure for projecting period and/or cohort effects into the future, and (4) model evaluation. For each of the seven single-population models from Cairns et al. (2009), the authors propose two population generalizations. They derive the criteria required to avoid long-term divergence problems and the likelihood functions for estimating the models. They also explain how the parameter estimates are found, and how the models are systematically simplified to optimize the fit based on the Bayes Information Criterion. Throughout the paper, the results and methodology are illustrated using real data from two pairs of populations.

In “Multi-Population Mortality Models: A Factor Copula Approach”, Hua Chen, Richard MacMinn and Tao Sun argue that modeling mortality co-movements for multiple populations have significant implications for mortality/longevity risk management. A small number of two-population mortality models have been proposed to date. These are typically based on the assumption that the forecasted mortality experiences of two or more related populations converge in the long run. This assumption might be justified by long-term mortality co-integration and thus be applicable to longevity risk modeling. It, however, seems too strong an assumption to model short term mortality dependence. The authors propose a two-stage procedure based on the time series analysis and a factor copula approach to model mortality dependence for multiple populations. In the first stage, they filter the mortality dynamics of each population using an ARMA-GARCH process with heavy-tailed innovations. In the second stage, they model the residual risk using a one-factor copula model that is widely applicable to high dimension data and very flexible in terms of model specification. They then illustrate how to use both their mortality model and the maximum entropy approach for mortality risk pricing and hedging. Their model generates par spreads that are very close to the actual spreads of the Vita III mortality bond. The authors also propose a longevity trend bond and demonstrate how to use this bond to hedge residual longevity risk of an insurer with both annuity and life books of business.

In "A Common Age Effect Model for the Mortality of Multiple Populations", Torsten Kleinow introduces a model for the mortality rates of multiple populations. To build the proposed model, the author investigates the extent to which a common age effect can be found among the mortality experiences of several countries and uses a common principal component analysis to estimate a common age effect in an age-period model for multiple populations. The fit of the proposed model is then compared to age-period models fitted to each country individually, and to the fit of the model proposed by Li and Lee (2005). Although the author does not consider stochastic mortality projections in this paper, he argues that the proposed common age effect model can be extended to a stochastic mortality model for multiple populations, which allows the generation of mortality scenarios simultaneously for all considered populations. This is particularly relevant when mortality derivatives are used to hedge the longevity risk in an annuity portfolio as this often means that the underlying population for the derivatives is not the same as the population in the annuity portfolio.

In "The Choice of Sample Size for Mortality Forecasting: A Bayesian Learning Approach", Hong Li, Anja De Waegenaere and Bertrand Melenberg argue that forecasted mortality rates using mortality models that have been proposed in the recent literature are sensitive to the sample size. In this paper, the authors propose a method based on Bayesian learning to determine model-specific posterior distributions of the sample sizes. In particular, the sample size is included as an extra parameter in the parameter space of the mortality model, and its posterior distribution is obtained based on historical performance for different forecast horizons up to 20 years. Age- and gender-specific posterior distributions of sample sizes are computed. The authors' method is applicable to a large class of linear mortality models. To illustrate, they focus on the first generation of the Lee-Carter model and the Cairns-Blake-Dowd model. Their method is applied to U.S. and Dutch data. For both countries, they find highly concentrated posterior distributions of the sample size that are gender and age-specific. In the out-of-sample forecast analysis, the Bayesian model outperforms the original mortality models with fixed sample sizes in the majority of cases.

In "Prospective Mortality Tables: Taking Heterogeneity into Account", Julien Tomas and Frederic Planchet illustrate an approach to constructing prospective mortality tables for which the data available are composed from heterogeneous groups observed during different periods. Without explicit consideration of heterogeneity, it is necessary to reduce the period of observation at the intersection of the different populations' observation periods. This reduction in the available history can influence the determination of the mortality trend and its extrapolation. The authors propose a model explicitly taking into account this heterogeneity, thereby preserving the entire history available for all populations. They use local kernel-weighted log-likelihood techniques to graduate the observed mortality. The extrapolation of the smoothed surface is performed by identifying the mortality components and their importance over time using singular value decomposition. Then time series methods are used to extrapolate the time-varying coefficients. The authors investigate the divergences in the mortality surfaces generated by a number of previously proposed models on three levels. These concern the proximity between the observations and the model, the regularity of the fit as well as the plausibility and consistency of the mortality trends.

Finally, in "Love and Death: A Freund Model with Frailty", Christian Gourieroux and Yang Lu introduce new models for analyzing the mortality dependence between individuals in a couple. The mortality risk dependence is usually taken into account in the actuarial literature by introducing special copulas with continuous density. This practice implies symmetric effects on the remaining lifetime of the surviving spouse. The new model allows for both asymmetric reactions by means of a Freund model, and risk dependence by means of an unobservable common risk factor (or frailty). These models allow us to distinguish, in the lifetime dependence, the component due to common lifetime (frailty) from the jump in mortality intensity upon death of a spouse (Freund model). The model is applied to the pricing of insurance products such as joint life policy, last survivor insurance, or contracts with reversionary annuities. A discussion of identification is also provided.

Subsequent to *L9, L10* took place in Santiago, Chile, on 3-4 September 2014. The *Journal of Risk and Insurance* will publish a Special Issue of selected papers presented at *L10*. *L11* will take place in Lyon, France, on 8–9 September 2015. *Insurance: Mathematics and Economics* will publish a Special Issue of selected papers presented at *L11*.

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