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Longevity Risk and Capital Markets: The 2009-2010 Update

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This Special Issue of the *North American Actuarial Journal* contains ten contributions to the academic literature all dealing with longevity risk and capital markets. Draft versions of the papers were presented at *Longevity Five: the Fifth International Longevity Risk and Capital Markets Solutions Conference* that was held in New York on 25-26 September 2009. It was hosted by J. P. Morgan and St John's University and organized by the Pensions Institute at Cass Business School, London, and the Edmondson-Miller Chair at Illinois State University.

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 Markets, i.e., the capital markets that trade longevity-linked assets and liabilities. 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 handle it to those willing to speculate in such risk for increased returns or who have a counterpoising risk that longevity risk can hedge, *e.g.*, life insurance. Many new investment products have been created both by the insurance/reinsurance industry and by the capital markets. Mortality catastrophe bonds are an example of a successful insurance-linked security. Some new innovative capital market solutions for transferring longevity risk include longevity (or survivor) bonds, longevity (or survivor) swaps and mortality (or q-) forward contracts. The aim of the *International Longevity Risk and Capital Markets Solutions Conferences* is to bring together academics and practitioners from all over the world to discuss and analyze these exciting new developments.

The conferences have followed closely the developments in the market. The first conference (*Longevity One*) was held at Cass Business School in London in February 2005. This conference was prompted by the announcement of the Swiss Re mortality

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catastrophe bond in December 2003 and the European Investment Bank/BNP Paribas/PartnerRe longevity bond in November 2004.

The second conference was held in April 2006 in Chicago and hosted by the Katie School at Illinois State University.[1] Since *Longevity One*, there had been further issues of mortality catastrophe bonds, as well as the release of the Credit Suisse Longevity Index. Life settlement securitizations were also beginning to take place in the US. 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 now 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 was held in Taipei, Taiwan on 20-21 July 2007. It was hosted by National Chengchi University.[2] It was decided to hold *Longevity Three* in the Far East, not only to reflect the growing importance of Asia in the global economy, but also in recognition of 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.[3] Since the Chicago conference, there had been many 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 contract or indemnification rather than a capital market transaction); the Institutional Life Markets Association was also launched in April 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.[4] 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

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

launched by Goldman Sachs, Genworth Financial, and National Financial Partners. ILS/ILA was 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).[5]

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[6] 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. There have been nine publicly announced longevity swaps in the UK since the beginning of 2008, covering five insurance companies' annuity books, three private sector pension funds and one local authority pension fund. The largest to date, covering £3bn of pension liabilities, was the longevity swap for the BMW (UK) Operations Pension Scheme, arranged by Deutsche Bank and Paternoster in February 2010, and involving a number of reinsurers, including Hannover Re, Pacific Life Re and Partner Re. The most recent swap to date, announced in February 2011, was between the Pall (UK) Pension Fund and J. P. Morgan: this was innovative in being the world's first swap to hedge the longevity risk of non-retired pension plan members. 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 was held in Amsterdam on 25-26 September 2008. It was hosted by Netspar and the Pensions Institute.[7] In 2008, Credit Suisse initiated a longevity swap with Centurion Fund Managers, whereby Centurion acquired a portfolio of synthetic (i.e., simulated) life policies, based on a longevity index built by Credit Suisse. In 2009, survivor swaps began to be offered to the market based on Deutsche Börse's Xpect Cohort Indices.

On 1 February 2010, the Life and Longevity Markets Association (LLMA) was established in London by AXA, Deutsche Bank, J. P. Morgan, Legal & General, Pension Corporation, RBS and Swiss Re. The original members were later joined by Morgan Stanley,

[5] In 2010, National Financial Partners became the sole owner of ILS/ILA.
[6] Coughlan et al. (2007).
[7] The conference proceedings for *Longevity Four* were published in the February 2010 issue of *Insurance: Mathematics and Economics*.

UBS and Aviva. LLMA was formed to promote the development of a liquid market in longevity- and mortality-related risks. This market is related to the insurance linked securities (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 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 Insurance-Linked Securities (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 longevity risk.

In January 2011, the Irish government issued 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.

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 (e.g., Blake et al. (2006), Bauer (2006), Bauer and Russ (2006), Denuit et al. (2007), Barbarin (2008), Bauer et al. (2010), Chen and Cummins (2010) and Kogure and Kurachi (2010)).
- Design and pricing of longevity-linked derivatives, such as survivor swaps (e.g., Dowd et al., 2006), survivor forwards and swaptions (e.g., Dawson et al., 2010), q-forwards (e.g., Brockett et. al., 2010) and mortality options (e.g., Milevsky and Promislow, 2001)
- Securitization and hedging (e.g., Cowley and Cummins (2005), Lin and Cox (2005), Dahl (2004), Dahl and Møller (2006), Friedberg and Webb (2007), Cox and Lin (2007), Denuit (2009), Wang et al. (2009), Biffis and Blake (2010), Wills and Sherris (2010), and Tsai et al. (2010))
- Mortality modelling and mortality term structure[8] modelling (e.g., Brouhns et al. (2002), Cairns et al. (2006, 2008a,b, 2009), Renshaw and Haberman (2006), Dowd et al. (2008), Blake et al. (2008), Hari et al. (2008), Biffis et al. (2009), Jarner and Kryger (2009), Plat (2009), Brockett et. al. (2010), Cox et al. (2010), and Yang et al. (2010))
- Improvements in the analysis and design of longevity-linked retail products (e.g., Gong and Webb (2010), and Stevens at al. (2010)).

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

It was also becoming clear that policy makers needed to have a greater understanding of the developments in the new Life Markets. This is because there is an important role for governments to play in helping these markets grow, namely by issuing longevity bonds. As argued in Blake et al. (2010), government-issued longevity bonds would allow longevity risk to be shared efficiently and fairly between generations. In exchange for paying a longevity risk premium, the current generation of retirees could look to future generations to hedge their aggregate longevity risk. There would also be wider social benefits. Longevity bonds would lead to a more secure pension savings market – both defined contribution and defined benefit – together with a more efficient annuity market resulting in less means-tested benefits and a higher tax take. The new Life Markets could get help to increase market participation through the establishment of reliable longevity indices and key price points on the mortality term structure and could build on this term structure with liquid longevity derivatives. There is increasing global support for government-issued longevity bonds (e.g., the UK Pension Commission (2005, p. 229), International Monetary Fund (2006), Antolin and Blommestein (2007), and World Economic Forum (2009)).

As mentioned before, not all paths to progress are smooth. In recent years, this has been particularly true in currently the largest market dealing with micro-longevity risk, namely life settlements.[9] The life settlements market has been dogged by systematic underestimates of policy holders' life expectancies by certain medical underwriters, issues concerning premium financing, frauds, and ethical issues associated with 'profiting' from individuals dying and policies maturing. In December 2009, Goldman Sachs announced it was closing down its QxX.LS index. This was partly because of the reputational issues associated with life settlements, but mainly because of insufficient commercial activity in the index. While the ethical issues are no different in substance from those relating to the macro-longevity market (see, e.g., Blake and Harrison, 2008), the micro-longevity market needs to learn some important lessons from the macro-longevity market. The macro-longevity market has been very successful at promoting good basic research on the analysis of the stochastic mortality forecasting models it uses and putting these models into the public domain and has also been much more transparent with the data it uses. This suggests a way forward for the life settlements micro market.

As with the previous conferences, *Longevity Five* consisted of both academic papers and more practical and policy-oriented presentations. The conference location in New York was motivated by the fact that US pension plans in the aggregate have the most significant exposure to longevity risk of pension plans anywhere in the world. The conference was addressed, among others, by the following keynote speakers:

[9] The market for micro-longevity risk trades assets involving a small number of lives. In the case of life settlements, for example, the products involve individual lives and hence are subject to a significant degree of idiosyncratic mortality risk. This contrasts with the market for macro-longevity risk which deals with pension plans and annuity books and hence involves a large number of lives: here idiosyncratic mortality risk is much less important than aggregate mortality risk which is essentially the trend risk of getting life expectancy projections wrong.

- Professor James Poterba, MIT and President of the National Bureau of Economic Research: Defined Contribution Plans, Mortality Risk, and the Demand for Annuities
- Tom Boardman, Prudential UK: Why Governments Should Issue Longevity Bonds
- Dr. John Iacovino, Fasano Associates: Longevity Extension – Dissecting Mortality Improvements over the Last Century
- Guy Coughlan, Managing Director and Global Head of LifeMetrics and Pension Solutions, J.P. Morgan: Population Basis Risk and Hedge Effectiveness
- Ari Jacobs and Martin Bird, Hewitt Associates: Pensioner Longevity Data Analysis and Applications
- Anthony Webb, Boston College: Valuing the Longevity Insurance acquired by Delayed Claiming of Social Security
- John Fitzpatrick, Pension Corporation: Aggregating Longevity Risk for the Capital Markets
- Scott Willkomm, Coventry: Micro-Longevity as an Alternative Asset Class
- Professor Richard MacMinn, Illinois State University: The Annuity Puzzle
- Professor Joe Coughlin, Age Lab, MIT: Retiring Retirement – Implications of Longer Worklife on Work, Pensions and Capital Markets

The academic papers that were selected by us as the editors of this Special Issue went through a refereeing process subject to the usual high standards of the *North American Actuarial Journal*. They cover the following themes: longevity risk hedges, the role of product design in mitigating the longevity risk facing annuity providers, the valuation of annuities and longevity bonds, and mortality modelling. We briefly discuss each of the 10 papers selected.

In 'Longevity hedging: A framework for longevity basis risk analysis and hedge effectiveness', Guy D. Coughlan, Marwa Khalaf-Allah, Yijing Ye, Sumit Kumar, Andrew J.G. Cairns, David Blake and Kevin Dowd show that basis risk is an important consideration when hedging longevity risk with instruments based on longevity indices, since the longevity experience of the hedged exposure may differ from that of the index. As a result, any decision to execute an index-based hedge requires a framework for (i) developing an informed understanding of the basis risk, (ii) appropriately calibrating the hedging instrument, and (iii) evaluating hedge effectiveness. The authors describe such a framework and apply it to two case studies: one for the UK (which compares the population of assured lives from the Continuous Mortality Investigation with the England & Wales national population) and one for the US (which compares the population of California with the US national population). The framework is founded on an analysis of historical experience data, together with an appreciation of the contextual relationship between the two related populations in social, economic and demographic terms. Despite the different demographic profiles, each case study provides evidence of stable long-term relationships between the mortality experiences of the two populations. This suggests the important result that high levels of hedge effectiveness should be achievable with appropriately-calibrated, static, index-based longevity hedges. Indeed, this is borne out in detailed calculations of hedge effectiveness for hypothetical pension portfolios where the basis risk is based on these case studies.

In ‘Measuring basis risk involved in longevity hedges’, Johnny S.H. Li and Mary R. Hardy also examine the basis risk in index longevity hedges for pension funds. They argue that it is important not to ignore the dependence between the population underlying the hedging instrument and the population being hedged. They consider four extensions to the Lee-Carter model that incorporate such dependence: (i) both populations are jointly driven by the same single time-varying index (k_t), (ii) the two populations are cointegrated, (iii) the populations depend on a common age factor, and (iv) an augmented common factor model in which a population-specific time-varying index is added to the common factor model with the property that it will tend towards a certain constant level over time. Using data from the female populations of Canada and US, the authors show the augmented common factor model is preferred in terms of both goodness-of-fit and ex-post forecasting performance. This model is then used to quantify the basis risk in a longevity hedge of 65-year old Canadian females structured using a portfolio of q-forward contracts predicated on US population mortality. The hedge effectiveness is estimated at 56% on the basis of longevity value-at-risk and 81.61% on the basis of longevity risk reduction.

In ‘Hedging longevity risk when interest rate are uncertain’, Larry Y. Tzeng, Jennifer L. Wang and Jeffrey T. Tsai propose an asset-liability management strategy to hedge the aggregate risk of annuity providers under the assumption that both the interest rate and mortality rate are stochastic. They assume that annuity providers can invest in a mix of longevity bonds, long-term coupon bonds and short-term zero-coupon bonds to hedge longevity and interest rate risks. Subject to a required minimum profit level for equity holders in the annuity provider, they show that the optimal allocation strategy leads to the lowest risk under different yield curve and mortality rate assumptions. A longevity bond is shown to be an effective hedging vehicle that significantly reduces the aggregate risk facing annuity providers.

In ‘Mortality-indexed annuities: Managing longevity risk via product design’, Andreas Richter and Frederik Weber also recognize that longevity risk has become a major challenge for governments, individuals and annuity providers in most countries. In its aggregate form, i.e. the systematic risk of changes to general mortality patterns, it has the potential for causing large cumulative losses for insurers. Since obvious risk management tools, such as (re)insurance or hedging, are less suited for managing an annuity provider’s exposure to this risk, the authors propose a type of life annuity with benefits contingent on actual mortality experience. Similar adaptations to conventional product design exist with investment-linked annuities, and a role model for long-term contracts contingent on actual cost experience can be found in German private health insurance. By effectively sharing systematic longevity risk with policyholders, insurers may avoid cumulative losses. Policyholders also gain in comparison with a comparable conventional annuity product: using a Monte-Carlo simulation, the authors identify a significant upside potential for policyholders while downside risk is limited.

In ‘A computationally efficient algorithm for estimating the distribution of future annuity values under interest-rate and longevity risks’, Kevin Dowd, David Blake and Andrew J. G. Cairns propose an efficient methodology for quantifying the impact of interest-rate risk and longevity risk on the distribution of annuity values in the distant future. The algorithm simulates the state variables out to the end of the horizon period and then uses a Taylor series approximation to compute approximate annuity values at the end of that period, thereby avoiding a computationally expensive ‘simulation-within-simulation’ problem. Illustrative results suggest that annuity values are likely to rise considerably, but are also quite uncertain. These findings have some unpleasant implications for both defined contribution pension plans and for defined benefit plan sponsors considering using annuities to hedge their exposure to these risks at some point in the future.

In ‘Human survival at older ages and the implications for longevity bond pricing’, Leslie Mayhew and David Smith focus on human survival at age 65, the starting age point for many pension products. Using a simple model, they link basic measures of life expectancy to the shape of the human survival function and consider its various forms. The model is then used as the basis for investigating actual survival in England & Wales. The authors find that life expectancy is increasing at a faster rate than at any time in history, with no evidence of this trend slowing or of any upper age limit. With interest growing in the use of longevity bonds as a way to transfer longevity risks from pension providers to the capital markets, the paper seeks to understand how longevity drift affects pension liabilities based on mortality rates at the point of annuitization versus what actually happens as a cohort ages. The main findings are that longevity bonds are an effective hedge against longevity risk; however, it is not only the oldest old that are driving risk, but also more 65 year olds reaching less extreme ages such as 80. In addition, they find that the possibility of future inflation and interest rates could be as an important a risk to annuities as longevity itself.

Mortality dynamics are characterized by changes in mortality regimes. In ‘Mortality regimes and pricing’, Andreas Milidonis, Yijia Lin and Samuel H. Cox describe a Markov regime switching model which incorporates mortality state switches into mortality dynamics. Using US population mortality data 1901-2005, the authors show that regime-switching models can perform better than well-known models in the literature. Furthermore, they extend the Lee-Carter model in such a way that the time-series common risk factor to all cohorts has distinct mortality regimes with different means and volatilities. Finally, they show how to price mortality securities with this model.

Katja Hanewald in ‘Explaining mortality dynamics: The role of macroeconomic fluctuations and cause of death trends’ uses data for six OECD countries over the period 1950–2006 to study the impact of macroeconomic fluctuations and cause of death trends on mortality dynamics in the Lee-Carter mortality forecasting model. The key results of this study are: (i) periods can be identified in which the Lee-Carter mortality index (k_t) correlates significantly with macroeconomic fluctuations, (ii) a few causes of death such as diseases of the circulatory system, influenza and pneumonia, and diabetes mellitus account for a large fraction of the variations in the mortality index, and (iii) most causespecific mortality rates show pronounced trends over the past decades. These trends change the composition of deaths and alter how total mortality reacts to external factors such as macroeconomic fluctuations.

Life insurance companies deal with two fundamental types of risks when issuing annuity contracts: financial risk and demographic risk. As regards the latter, recent work has focused on modeling the trend in mortality as a stochastic process. A popular method for modeling death rates is the Lee-Carter model. This methodology has become widely used and there have been various extensions and modifications proposed to obtain a broader interpretation and to capture the main features of the dynamics of mortality rates. In order to improve the measurement of uncertainty in survival probability estimates, in particular for older ages, Valeria D'Amato, Emilia Di Lorenzo, Steven Haberman, Maria Russolillo and Marilena Sibillo in "The Poisson log-bilinear Lee-Carter model: Applications of efficient bootstrap methods to annuity analyses" propose an extension based on simulation procedures and on the bootstrap methodology. The paper aims to obtain more reliable and accurate mortality projections, based on the idea of obtaining an acceptable accuracy of the estimate by means of variance reducing techniques. In this way, the forecasting procedure becomes more efficient. The longevity question constitutes a critical element in the solvency appraisal of pension annuities. The demographic models used for the cash flow distributions in a portfolio impact on the mathematical reserve and surplus calculations and affect the risk management choices for a pension plan. The paper extends the investigation of the impact of survival uncertainty for life annuity portfolios and for a guaranteed annuity option in the case where interest rates are stochastic. In a framework in which insurance companies need to use internal models for risk management purposes and for determining their Solvency Capital Requirement, the authors consider the surplus value, calculated as the ratio between the market value of the projected assets to that of the liabilities, as a meaningful measure of the company's financial position, expressing the degree to which the liabilities are covered by the assets.

Finally, in 'A gravity model of mortality rates for two related populations', Kevin Dowd, Andrew J.G. Cairns, David Blake, Guy D. Coughlan, and Marwa Khalaf-Allah show that the mortality rate dynamics between two related but different-sized populations can be modeled consistently using a new stochastic mortality model which they call the gravity model. The larger population is modeled independently and the smaller population is modeled in terms of spreads (or deviations) relative to the evolution of the former, but the spreads in the period and cohort effects between the larger and smaller populations depend on gravity or spread reversion parameters for the two effects. The larger the two gravity parameters, the more strongly the smaller population's mortality rates move in line with those of the larger population in the long run. This is important where it is believed that the mortality rates between related populations should not diverge over time on grounds of biological reasonableness. The model is illustrated using an extension of the Age-Period-Cohort (APC) model and mortality rate data for English & Welsh males representing a large population and the Continuous Mortality Investigation assured male lives representing a smaller related population.

We would like to express our sincere gratitude to all the referees and also to Mary Hardy for her support during the preparation of this volume. Most of all, we would like to thank the authors for their fine contributions.

Longevity Six took place in Sydney on 9-10 September 2010, hosted by the Australian Institute of Population Ageing Research at the Australian School of Business, University of New South Wales. The *Geneva Papers on Risk and Insurance - Issues and Practice* will publish a Special Issue of selected papers presented at the conference. *Longevity Seven* will take place in Frankfurt on 8-9 September 2011. The *Journal of Risk and Insurance* will publish a Special Issue of selected papers presented at this conference.

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