DISCUSSION PAPER PI-1806

Longevity Risk and Capital Markets: The 2016-17 Update.

David Blake and Richard MacMinn

August 2018

ISSN 1367-580X

The Pensions Institute
Cass Business School
City, University of London
106 Bunhill Row
London EC1Y 8TZ
UNITED KINGDOM
http://www.pensions-institute.org/

Longevity Risk and Capital Markets: The 2016-17 Update

David Blake
Richard MacMinn[+]

14 August 2018

This Special Issue of the *North American Actuarial Journal* contains 14 contributions to the academic literature all dealing with longevity risk and capital markets. Draft versions of the papers were presented at *Longevity 12: The Twelfth International Longevity Risk and Capital Markets Solutions Conference* that was held in Chicago on 29-30 September 2016. It was hosted by the Society of Actuaries (SOA) and the Pensions Institute.

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

As with the previous conferences, *Longevity 12* consisted of both academic papers and more practical and policy-oriented presentations. There were four plenary sessions: The Demographics of Longevity Risk, Product Innovation, Data Reliability Challenges and Timeliness, and Mortality Forecasting in Practice. The following keynote speakers presented at these sessions:

[+] David Blake [D.Blake@city.ac.uk] is Professor of Pension Economics and Director of the Pensions Institute, Cass Business School, City University of London, United Kingdom. Richard MacMinn is Visiting Fellow at the University of Texas, United States and National Chengchi University, Taiwan [richard@macminn.org]. David Blake and Richard MacMinn are Co-Founders of the *Longevity Risk and Capital Markets Solutions Conferences.* They are extremely grateful to Dale Hall and his staff at the Society of Actuaries for their superb organization of the conference.

- Jay Olshansky (University of Illinois at Chicago) discussed "The Rise and Fall of Human Longevity in the 21st Century" and asked the question: “Can we really add decades of life to people aged 70+ today faster than we added decades of life to children born in the early 20th century?”. His answer was “no”, in large part due to the global obesity pandemic.
- Aubrey de Grey (Chief Science Officer of SENS Research Foundation) spoke about “Longevity Escape Velocity: Incorporating Technological Progress into Extrapolation”. He argued that ageing is the accrual of living-derived damage and that damage can foreseeably be repaired using rejuvenation biotechnology.
- Sam Gutterman (Retired Director and Consulting Actuary, PricewaterhouseCoopers) discussed “Longevity – The Dark Side”. He explained that recently in the U.S., there has been a slowdown in mortality reductions and that previous improvement in cardiovascular disease mortality will be hard to duplicate in future.
- Vladimir Canudas-Romo (Max Planck Odense Centre on the Biodemography of Aging, University of Southern Denmark) presented on “The Past and Future Rise of Human Longevity”. He used three models to show that U.S. life expectancy continues to increase. Further, new cohorts had higher education and this is generally associated with higher life expectancy.
- Richard L. Sandor (Founder of the Chicago Climate Exchange) gave a talk on “Financial Innovation” and explained that keeping regulators in the loop was one of the most important factors determining the success of a new market.
- Amy Kessler (Prudential Financial, Inc.) discussed “New Solutions to an Age-Old Problem: Innovative Strategies for Managing Pension and Longevity Risk”. She described how the last decade had seen the spread of U.K. de-risking techniques to other countries, and this had brought both customization and increased capacity. Although many problems had been solved, there was more work to do, such as helping pension funds start on the road to de-risking, despite the environment of low interest rates, bringing de-risking to more countries, and introducing risk transfer solutions for Dutch-style collective DC plans.
- Laura Hardy (RGA Life Reinsurance Company) spoke about “Longevity Risk Transfer: Where does the Market Turn when all the Cheap Capacity is Gone?”. She explained how the growth in capacity the U.K. longevity de-risking market was explained, in part, by international, mainly U.S., insurers seeking a hedge for their own mortality risk exposure. But the capacity generated from the global mortality market could only support a fraction of total U.K. longevity exposure. She pointed to the following barriers to low-cost capital markets capacity: the tenor of the exposure is too high, the exposure is uncapped, and there is also poor pricing transparency, volatility, and the impact of medical advances. Laura offered the following solutions for bridging the gap: greater use of insurers to help share the risk (e.g., via fixed term annuities, tontines, high retentions), greater use of capital markets to hedge the risk (e.g., by combining with other risks/blocks and making use of a published national longevity index) and using reinsurers to limit the risk (e.g., via fixed-term swaps, out-of-the money swaps, and top slicing).
- Vladimir Nicenko (Willkie Farr & Gallagher), Nicholas Bugler (Wilkie Farr & Gallagher), Amy Kessler (Prudential Financial, Inc.) and Chip Gillis (Athene Life

Re) gave a presentation entitled “Sidecars: Alternative Capital or Reinsurance?”. They explained that sidecars were special purpose reinsurance vehicles with the following properties: short duration (2-3 years); capitalized by specialist insurance funds, usually by preference shares, though sometimes in the form of debt instruments; reinsured a defined pre-agreed book of business or categories of risk; have liability limited to the assets of the special purpose vehicle (SPV); and are unrated. They are attractive for insurers because they provide: insurers with protection against peak risks, additional capacity without the need for permanent capital, and an additional source of income by leveraging underwriting expertise. They are attractive for investors because they: provide targeted non-correlated returns relating to specific risks, are short-tail in nature with an agreed procedure for exiting, take advantage of price hikes, and involve no legacy issues that could affect an investment in a typical insurer. This, of course, involves challenges when it comes to using sidecars in the life sector: which is long term in nature, in contrast with investors’ short term horizons; which brings regulatory requirements on ceding insurers impacting their ability to generate a return; which requires prudent collateral; where the underlying assets of the SPV must generate matching cash flows; which must involve true “risk-transfer” for the cedants to attract capital relief; which require a financially strong custodian/trustee; and where investor exit is not easy due to lack of liquidity.

- Magali Barbieri (Associate Director, Human Mortality Database) discussed "Data Quality Issues and Adjustments in the Human Mortality Database (HMD)". The HMD is one of the most widely used databases in global longevity risk transfer, so it is important to understand the data challenges involved in running the HMD. These include: the availability and timeliness of input data, the granularity of available data (e.g., by single year, 5-year or 10-year age grouping), changes in definition over time (e.g., the definition of a live birth), and the reliability of the information provided (e.g., under-registration (births, deaths, population), unknown age or age misstatement).
- Steve Goss (Social Security Administration) spoke about “The Importance of Consistent Data on Deaths and Exposure over Time, by Age, Sex, and Cause of Death” and the implications for Social Security, Medicare and other insurance/benefit plans in the U.S.
- Tom Jones (Prudential Financial, Inc.) presented on "The Importance of High Quality Data for Underwriting Pension Risk Transfer (PRT) and Longevity Reinsurance Transactions (LRTs): An Insurance Company Perspective". He said that the quality of mortality and marital data is critical for accurately assessing the value of liabilities. For a PRT transaction, where there is a single premium paid upfront, the assumption set applies for the next 30-50 years and hence it becomes paramount to get accurate data. The marital assumption and the spousal benefit on the primary participant’s date of death are critical assumptions for LRTs. They lead to huge tail risk in the liability and most of the data sources on the marital assumption do not capture “young spousal risk” (as a result of death bed marriages).
- Karen P. Glenn (Social Security Administration) discussed “Projecting Mortality by Age and Cause: The Importance of Data Source, Expert Judgment, and Unknown Future Challenges”. She explained how the SSA assumes that mortality

will continue to decline in the future, but it is the rate of decline that is in question. The SOA uses three sets of projections (intermediate, low cost, and high cost) which depend, in part, on expert judgment.

- Laurence Pinzur (Aon Hewitt) discussed "The Continuing Evolution of the Retirement Plans Experience Committee's (RPEC's) Mortality Projection Methodology". The U.S. RPEC model is based on the same conceptual underpinnings as the U.K.'s CMI (Continuous Mortality Investigation) model. Prior to 2009, RPEC was primarily interested in developing tables of base mortality rates for retirement-related applications in the U.S. However, the Mortality Improvement (MI) subcommittee of RPEC has been very busy since 2009. RPEC assumes that recently observed experience is the best predictor of future near-term mortality improvement rates, while long-term rates of mortality improvement are based on "expert opinion" and the analysis of longer-term mortality patterns.
- Vladimir Canudas-Romo gave a second presentation, this time on "Mortality Expectations by Cause through 2040: Johns Hopkins Clinicians and Researchers". The presentation described a study that used expert opinion to estimate likely changes in the prevention and treatment of important disease conditions and how they will affect future life expectancy. Focus groups were held including clinical and public health faculty with expertise in the six leading causes of death in the U.S. Mortality rates and life tables for 2040 were derived by sex and age. Life expectancy at age 20 and 65 was compared to figures published by the SSA and to estimates from the Lee-Carter method. There was agreement among all three approaches that life expectancy at age 20 will increase by approximately one year per decade for females and males between now and 2040. According to the clinical experts, 70% of the improvement in life expectancy will occur in cardiovascular disease and cancer, while in the last 30 years, most of the improvement has occurred in cardiovascular disease. Expert opinion suggests that most of the increase in life expectancy will be attributable to the already achieved reduction in smoking rates, especially for women.
- Jay Olshansky also gave a second talk, this time on "Understanding Biology: Going Beyond Simple Statistical Extrapolation". He explained some key common sense, biological and demographic rules that are bent or broken by assuming linear increases in life expectancy: Rule # 1, linear extrapolations of biological phenomenon are inherently dangerous; Rule # 2, aging gets in the way; Rule # 3, life expectancy is an inherently bad metric to forecast; and Rule # 4, Zeno's Paradox of Immortality, a classic example of this being the statement that death rates can forever decline by half, on the grounds that there is no lower bound on death rates other than zero.
- Finally, Steve Goss spoke about "Projecting Mortality, Different Models for Different Purposes and Views About the Future". He discussed projections based on data (i.e., extrapolating past trends) and projections by age, sex, and cause. He also considered what future conditions might change, e.g., a decline in female smoking, a continued increase in obesity, and a deceleration in health spending, especially in the U.S.

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 the *North American Actuarial Journal*. They cover the following themes: developing the longevity risk transfer market, longevity risk hedging, longevity risk in insurance policies and annuities, the role of annuities in portfolios and long-term care solutions, age/period/cohort mortality models, and improving mortality estimates using fertility data. We briefly discuss each of the 14 papers selected.

In "New solutions to an age-old problem: Innovative strategies for managing pension and longevity risk", Amy Kessler points out that, while the pension and longevity risk transfer market is barely a decade old, over $360 billion USD in global transactions have already taken place, mainly in the United Kingdom, the United States, Canada and the Netherlands. The main deals have been buy-outs, buy-ins and longevity swaps for pension plans. Similar de-risking solutions have spread to the market for insured annuities. She argues that transactions must be simplified, standardized and made available to all pension plans, regardless of size. They must also cover younger deferred plan participants, as well as those in collective plans where inter-generational risks are important. New investors must be brought in and one way of doing this is via sidecars. Capital relief is important in reducing the costs of insurance-based solutions, such as those involving tail-risk protection. Regulators need to become more comfortable with such deals.

Nicholas Bugler, Kirsty Maclean, Vladimir Nicenko, and Patrick Tedesco write about "Re-insurance side-cars: The next stage in the development of the longevity risk transfer market". Transaction structures involving reinsurance sidecars can be adapted to benefit cedants and sponsoring reinsurers and also to attract a broader spectrum of investors and participants by reducing the long-tail risk inherent in longevity risk transfer. While several transaction structures are possible, each would fundamentally provide additional capital to support transactions in a form that is not subject to a requirement to hold a regulatory solvency capital buffer, thereby enabling sponsoring reinsurers to offer keener pricing to cedants. As a result, an EU-based cedant could gain considerable capital benefits by reinsuring longevity risk, market risk or both to a reinsurance sidecar.

In "Optimal longevity risk transfer and investment strategies", Samuel H. Cox, Yijia Lin and Sheen Liu recognize that there has been a surge of activities in recent years by defined benefit (DB) plan sponsors to transfer their pension risk through strategies such as buy-ins and buy-outs. As buy-in and buy-out transaction pipelines grow, insurers actively participating in the buy-in and buy-out markets are exposed to significant longevity risk embedded in pension plans. In this paper, the authors investigate how to maximize a bulk annuity insurer's value with reinsurance and/or longevity securities, subject to constraints that control longevity and investment risks as well as overall risk. They apply duality and the martingale approach to derive an optimal longevity risk transfer strategy. The results show that longevity risk transfer interacts with an insurer's investment decision for value maximization. The analysis also highlights the interdependence of different longevity risk management tools to achieve an overall risk target.

In “Longevity Greeks: What do insurers and capital market investors need to know?”, Kenneth Q. Zhou and Johnny S.-H. Li argue that there is a role for the capital markets in sharing some of the huge longevity risk exposures borne by the pension and life insurance industries. The transfer of risk can be accomplished by trading standardized derivatives such as *q*-forwards that are linked to published mortality indexes. To strategize such trades, it is possible to utilize “longevity Greeks”, which are analogous to equity Greeks that have been used extensively in managing stock price risk. The authors derive three important longevity Greeks – delta, gamma and vega – on the basis of an extended version of the Lee-Carter model that incorporates stochastic volatility. They then study the properties of each longevity Greek, and estimate the levels of effectiveness that different longevity Greek hedges can possibly achieve. The results reveal several interesting facts; for example, in a delta-vega hedge formed by *q*-forwards, the choice of reference ages does not materially affect hedge effectiveness, but the choice of times-to-maturity does. These observations may help insurers to better formulate their hedge portfolios, and issuers of mortality-linked securities to determine what security structures are more likely to attract liquidity.

Andrew J.G. Cairns and Ghali El Boukfaoui write about “Basis risk in index based longevity hedges: A guide for longevity hedgers”. They undertake an assessment of longevity basis risk in the context of a general index-based hedge. They develop a detailed framework for measuring the impact of a hedge on regulatory or economic capital that takes population basis risk explicitly into account. The framework is set up in a way that accommodates a variety of regulatory regimes such as Solvency II as well as local actuarial practice, attempting, therefore, to bridge the gap between academia and practice. This is followed by a detailed analysis of the capital relief resulting from a hedge that uses a call spread as the hedging instrument. The authors find that the impact of population basis risk on capital relief (expressed in terms of a “haircut” (i.e., the reduction in regulatory capital) relative to the case with no population basis risk) depends strongly on the exhaustion point of the hedge instrument. In particular, in a Solvency II setting, if the exhaustion point lies well below the 99.5% Value-at-Risk, population basis risk has negligible impact and the haircut is zero.

In “Mortality risk management under the factor copula framework - with applications to insurance policy pools”, Ming-Hua Hsieh, Jason C. Tsai, and Jennifer L. Wang point out that mortality risk is one of the core risks that life insurers face. The uncertain future lifetime of each insured represents one risk factor, and the dependence structure among these risk factors determines the aggregate risk of an insurance policy pool. The authors use factor copulas to describe the dependence structure among the future lifetimes of numerous insureds. To mitigate the systematic mortality risk associated with an insurance pool, the insurer may purchase an asset exposed to similar systematic risk. The authors set up a two-factor copula framework and solve for the optimal investment amount in the asset. In numerical illustrations, they employ real-case data from a life insurer and a life settlement market maker involving hundreds of policies.

In “Understanding patterns of mortality homogeneity and heterogeneity across countries and their role in modelling mortality dynamics and hedging longevity risk”, Sharon S.

Yang, Yu-Yun Yeh, Jack C. Yue, and Hong Chih Huang argue that understanding patterns of mortality homogeneity and heterogeneity across countries can assist in modelling mortality dynamics and in hedging longevity risk. This study proposes a methodology, based on the graduation method, to detect differences in mortality rates across different populations. Using an index based on the Partial Standard Mortality Ratio, the authors measure mortality homogeneity and heterogeneity, then conduct an empirical study across countries with emerging and developed markets. The results of model fitting show that it is inappropriate to use a coherent mortality model for the mortality-heterogeneous populations. In an application, the authors demonstrate that a reinsurer can utilize information concerning mortality homogeneity/heterogeneity for pooling risk in its books of life insurance and annuity businesses and increase overall hedge effectiveness. The coherent mortality model can help reduce the volatility of the reinsurer's profit and help the reinsurer diversify its longevity risk across homogeneous populations.

Qiheng Guo and Daniel Bauer write about "Different shades of risk: Mortality trends implied by term insurance prices". To infer forward-looking, market-based mortality trends, the authors estimate a flexible affine stochastic mortality model based on a set of US term life insurance prices using a generalized method of moments approach. They find that neither mortality shocks nor stochasticity in the aggregate trend seem to affect the prices. In contrast, allowing for heterogeneity in the mortality rates across carriers is crucial. The authors conclude that for life insurance, rather than aggregate mortality risk, the key risks emanate from the composition of the portfolio of policyholders. These findings have consequences for mortality risk management and emphasize important directions of mortality-related actuarial research.

In "Hedging annuity risks with the age-period-cohort two-population gravity model", Kevin Dowd, Andrew J.G. Cairns, and David Blake consider the effectiveness of an illustrative annuity hedging problem in which a forward annuity predicated on one population is hedged by a position in a forward annuity predicated on another population. Their analysis makes use of the age-period-cohort two-population gravity model that takes account of the observed inter-dependence between the two populations' mortality rates; it also considers the implications of parameter uncertainty, individual death or Poisson risk and interest-rate risk for hedge effectiveness. The authors consider horizons of up to 20 years. For the most part, the results are robust and indicate strong hedge effectiveness, with estimates of relative risk reduction varying from about 0.70 in the least effective case to well over 0.95 in the most effective cases.

Ralph Rogalla writes about "Optimal portfolio choice in retirement with participating life annuities". He derives optimal consumption, investment, and annuitization patterns for retired households that have access to German-style participating payout life annuities (PLAs), allowing for capital market risks as well as idiosyncratic and systematic longevity risks. PLAs provide guaranteed minimum benefits in combination with participation in insurers' surpluses. Minimum benefits are calculated based on conservative assumptions regarding capital market and mortality developments, while surpluses distributed to annuitants bridge the gap between the insurers' actual investment and mortality experiences and the projections used in pricing. Through the participation plan, systematic

longevity risk is shared between insurers and annuitants, as unanticipated longevity shocks result in benefit adjustments via the surplus mechanism. The author shows that the retiree draws substantial utility from access to PLAs, equivalent to 20% of initial wealth in the presence of systematic longevity risk. He also finds that stochasticity in mortality rates only has a minor impact on the appeal of PLAs to the retiree. Even if the interest rate guarantee is reduced to zero in adverse capital market environments, PLAs prove to provide substantial utility for retirees. Overall, the participating life annuity design produces substantial welfare gains over a no-annuity world, while being an effective setup that helps providers manage long-term risks that are difficult to hedge otherwise, such as systematic longevity risks.

In “Flexible and affordable methods of paying for long-term care insurance”, Les Mayhew, Ben Rickayzen and David Smith argue that with the expected dramatic increase in the number of older people requiring care, and the tightening of public funding, individuals will be increasingly expected to contribute to, and plan for, their own care in later life. However, history shows us that people are very reluctant to save for their care to the extent that there are no longer any providers of traditional pre-funded long-term care insurance products in the U.K. to help address this problem. In this paper, the authors consider a product which is a disability-linked annuity that provides benefit payments towards the cost of both domiciliary and residential nursing care. They investigate different ways in which individuals can purchase this product with the goal of minimizing the impact on their living standards, hence making the purchase of the product more palatable. As well as the traditional methods of purchasing insurance out of income and savings, they show that this product can also be purchased by making use of assets such as residential property. This flexibility would allow individuals to have control over the timing of their payments to fit around their lifestyle, particularly those with low retirement incomes. It follows that some people will be more attracted to particular payment methods than others and a framework is presented which segments people according to individual circumstances. A model is developed showing how the annuity works and how premiums are calculated.

In “On the structure and classification of mortality models”, Andrew Hunt and David Blake point out that there has recently been a huge increase in the use of models which examine the structure of mortality rates across the dimensions of age, period and cohort. This paper reviews the major developments in the field and provides a holistic analysis of these models and examines their similarities and differences. Specifically, it reviews the models that have been proposed to date, investigates the structure of age/period/cohort mortality models, introduces a classification scheme for existing models and lists the key principles a model user should consider when constructing a new model in this class.

Andrew Hunt and David Blake go on to take “A Bayesian approach to modelling and projecting cohort effects”. They point out that one of the key motivations in the construction of ever more sophisticated mortality models was the realization of the importance of ``cohort effects'' in the historical data. However, these are often difficult to estimate robustly, due to the identifiability issues present in age/period/cohort mortality models, and exhibit spurious features for the most recent years of birth, for which there is little data. These can cause problems when the model is projected into the future. In this

study, the authors show how to ensure that projected mortality rates from the model are independent of the arbitrary identifiability constraints needed to identify the cohort parameters. They then go on to develop a Bayesian approach for projecting the cohort parameters, which allows fully for uncertainty in the recent parameters due to the lack of information for these years of birth, which leads to more reasonable projections of mortality rates in future.

Finally, in “Improving HMD mortality estimates with HFD fertility data”, Alexandre Boumezoued aims to improve mortality estimates using fertility data. Estimating the population exposed to risk – such as in the Human Mortality Database (HMD) – can suffer from errors for cohorts born in years in which births fluctuate unevenly over the year. When comparing period and cohort mortality tables, the author highlights the presence of anomalies in the period tables in the form of isolated cohort effects. His investigation of the HMD methodology shows that it assumes a uniform distribution of births that is specific to the period tables and this is likely to lead to an asymmetry with the cohort tables. Building on the “Phantoms Never Die” study of Cairns et al (2016) regarding the construction of a "data quality indicator", the author utilizes the Human Fertility Database (HFD) which he regards as the perfect counterpart to the HMD in terms of fertility. The indicator is then used to construct corrected period mortality tables for several countries, which the author then analyses from both an historical and prospective point of view. The analysis has implications for the reduction of volatility of mortality improvement rates, the use of cohort parameters in stochastic mortality models, and the improved fit of corrected tables by classical mortality models.

Longevity 13 took place in Taipei, Taiwan on September 21–22, 2017. The *North American Actuarial Journal* will publish a Special Issue of selected papers presented at this conference. *Longevity 14* will take place in Amsterdam on September 20–21, 2018. *Annals of Actuarial Science* will publish a Special Issue of selected papers presented at this conference.

Reference

Cairns, A. J. G., Blake, D., Dowd, K., Kessler, A.R. (2016) Phantoms never die: living with unreliable population data, *Journal of the Royal Statistical Society (Series A)*, 179 (4), 975-1005.