CEPAR Longevity Risk Workshop November 2022
Retirement Income: Risks and Solutions

Monday, 28 November 2022, UNSW, Sydney

Location:
Chemical Sciences Building CSc M10, UNSW Sydney

8.45AM	**Registration**
9.00AM	**Michael Sherris, UNSW** *"A Short Ramble Through the Affine Mortality Model Countryside"* **Francesco Ungolo, UNSW** *"Estimation, Comparison and Projection of Multi-factor Age-Cohort Affine Mortality Models"*
10.00AM	**BREAK**
10.15AM	**Andres Villegas, UNSW** *"R Modules for Retirement Income Risk and Products: UNSW Retirement Income Toolkit"* **Yawei Wang, UNSW** *"A unified Markov Chain Monte Carlo framework for valuation and assessment of retirement income products."*
11.15AM	**MORNING TEA**
11.30AM	**David Bell, Executive Director, The Conexus Institute** **Estelle Liu, Actuarial Practice Lead, Aware Super** **Victor Huang, Principal and Head of Investment Solutions Asia-Pacific, Millliman** *"Practitioner Perspectives"*
12.30PM	**LUNCH BREAK**
1.30PM	**Kyu Park, UNSW** *"Pricing Long-term Care Insurance in Australia Considering Health and Chronic illness."*

	Len Patrick Dominic M. Garces, UNSW *"Variable annuities: a closer look at ratchet guarantees, hybrid contract designs, and taxation"*
2.30PM	**AFTERNOON TEA**
3.00PM	**Michelle Vhudzijena, UNSW** *"Modelling mortality and functional disability risks using hidden Markov models* *with covariates."* **Salvatory Kessy, UNSW** *"Averaging Mortality Rate Forecasts Across Fitting Periods."*
4.00PM	**WORKSHOP CONCLUDES**

Abstracts (in order of presentation)

A Short Ramble Through the Affine Mortality Model Countryside – Michael Sherris

This talk will provide an overview of recent and ongoing collaborative research on affine mortality models. It will introduce the affine mortality model setting for the auto-regressive dynamics of mortality rates, the survival function consistent with these dynamics, model estimation, R code for affine models, and then illustrate results from a cross country comparison focussing on 3 factor models and on USA mortality data. It will outline current research on estimating age-cohort survival curves incorporating incomplete cohort data, more general factor models, squared Gaussian models to capture gamma distributed mortality rates, incorporation of jumps to capture period effects such as pandemics and wars, and age dependence in drift and volatility. The research is motivated by Retirement, Annuity, and Superannuation applications requiring a stochastic mortality model with analytical age-cohort survival curves that can readily incorporate prices of risk.

Estimation, Comparison and Projection of Multi-factor Age-Cohort Affine Mortality Models- Francesco Ungolo

Affine mortality models, developed in continuous time, are well suited to longevity risk applications including pricing and capital management. A major advantage of this mortality modelling approach is the availability of closed-form cohort survival curves, consistent with the assumed time dynamics of mortality rates. This paper makes new contributions to the estimation of multi-factor continuous-time affine models including the canonical Blackburn-Sherris, the AFNS and the CIR mortality models. We discuss and address numerical issues with model estimation. We apply the estimation methods to age-cohort mortality data from five different countries, providing insights into the dynamics of mortality rates and the fitting performance of the models. We show how the use of maximum likelihood with the univariate Kalman filter turns out to be faster and more robust compared to traditional estimation methods which heavily use large matrix multiplication and inversion. We present graphical and numerical goodness-of-fit results and assess model robustness. We project cohort survival curves and assess the out-of-sample performance of the models for the five countries. We also show how these affine mortality models are robust with respect to the set of age-cohort data used for parameter estimation. Furthermore, we briefly provide an overview on the extension of such models to account for jumps and the estimation challenges they present. The modelling and estimation framework is accompanied by the Github repository affine mortality, which allows to efficiently estimate the model parameters in R

Modelling Retirement Income Risks and Solutions: A Retirement Income Toolkit in R – Andres Villegas

Financing and modelling of retirement risks has been the focus of actuarial research over recent years. Much of this research has involved the development and application of models implemented with various software. A Retirement

Income Toolkit has been developed in R that implements many of these models for development and application by researchers in modelling retirement income risks and product solutions. The Toolkit includes modules that implement models of systematic mortality, functional disability and health status, economic scenario generators and retirement product cash flow simulation and pricing. This paper/presentation outlines the main features of the Retirement Income Toolkit including the models and the output from the modules and a discussion of the applications and extensions of the Toolkit in research and practical applications.

A unified Markov Chain Monte Carlo framework for valuation and assessment of retirement income products – Yawei Wang

This paper devises a flexible framework assessment of a catalogue of existing retirement income products which include, account-based pension, life annuities, variable annuities, and group self-annuities. It utilises Hamiltonian Monte Carlo approach; a proven computational technique for simulating conditional distributions without prior knowledge of the normalizing constant and quickly converges to the target distribution in high dimensions. A metric for assessing the risk-return trade-offs for each product is presented which can readily be adapted by advisors, and all stakeholders as a tool for enhancing the decision-making process for retirees. This research addresses key recommendations from Australia's retirement income covenant which mandates trustees of superannuation funds in developing strategies aimed at i) maximising expected retirement income, ii) managing longevity, investment, and inflation risks, and iii) enhancing flexibility in accessing

Pricing Long-term Care Insurance in Australia Considering Health and Chronic illness – Kyu Park

In a prior study, we have developed and estimated a multi-state Markov model of functional disability (based on core activity limitations) and chronic illness status for Australians aged 60 or greater. The model explains transitions between five states (healthy, disabled but not ill, ill but not disabled, disabled and ill and dead) with age, sex, and trend factors. Estimation of the model utilised four unlinked cross-sectional data sets with prevalence of disability and illness across 10 years (data in the Survey of Disability, Ageing and Caring 2009, 2012, 2015 and 2018), and aimed to estimate the transition rate parameters that best explained the observed changes of prevalence in Australia. In this paper we price a long-term care (LTC) insurance considering health and chronic illness for Australians based on the estimated model. For the product design, we consider existing LTC insurance products in the US and UK, the applicability in the Australian context, and integration with a life annuity. Sensitivity tests for model and product parameters are performed. R codes for the pricing are provided.

Variable annuities: a closer look at ratchet guarantees, hybrid contract designs, and taxation – Len Garces

In recent years, commercial providers of variable annuity (VA) contracts have launched products which offer potentially higher minimum guaranteed benefits through a ratcheting mechanism in conjunction with an array of investment options, including a cash fund. In some VA contract designs, the cash fund serves as an intermediate repository of earnings from the VA. For example, in a VA with a guaranteed minimum withdrawal benefit (GMWB), the policyholder has the option to withdraw less than the guaranteed withdrawal amount, with the difference being deposited into the cash fund, which will continue to appreciate at a rate benchmarked against cash rates offered by central banks. In this presentation, we consider the valuation of a VA contract with a GMWB rider in which the policyholder has access to a cash fund. Following commercially available offerings of VAs with a ratcheting mechanism for the guaranteed benefit, we formulate a mathematical model to determine an optimal withdrawal strategy and provide numerical examples of cash flows emanating from the contract. We also investigate the implications of taxation on the value of the VA contract. In the process, we also discuss related academic literature dealing with the mathematical valuation of VAs with path-dependent guarantees and of VAs with more than one guaranteed benefit. This is ongoing work in collaboration with Jennifer Alonso-Garcia and Jonathan Ziveyi.

Modelling mortality and functional disability risks using hidden Markov models with covariates- Michelle Vhudzijena

Multi–state Markov models are commonly used to price long term care insurance and health linked annuities. Disregarding health status in mortality modelling can cause adverse selection. However, there is no link in the literature between health status and individual level risk factors such as body mass index, household income and self–reported health. In this paper we use k–medoids clustering to group health trajectories estimated using hidden Markov models with covariates and place individuals with similar mortality risk profiles in the same groups. We verify if this clustering improves the estimation of transition rates among the different states of a three-state health and functional disability model. We find that clustering provides a better fit to empirical data. We can identify three clusters with distinct risk factors that exhibit mortality heterogeneity. Differences in life expectancy, healthy life

expectancy and age at onset of disability persist in old age. Not accounting for differences has significant impact on the demand, pricing and reserving of health-related insurance products. Our results are relevant to insurers, annuity providers and pension providers.

Averaging Mortality Rate Forecasts Across Fitting Periods – Salvatory Kessy.

An essential aspect of estimating many commonly used mortality models is the selection of fitting period. This is especially important considering changing mortality trends. Trend extrapolation requires determining the length of the base period. Many mortality models proposed in literature assume a random walk with drift for trends to forecast mortality rates. For this assumption, mortality rate forecasts are highly sensitive to the calibration period, especially with changing mortality trends and structural changes in mortality patterns. One approach to this problem is to average mortality rate forecasts from the single model but calibrated across multiple starting points to account for structural changes and the impact of the fitting period. We use this approach with Generalized Age-Period-Cohort (GAPC) mortality models to obtain mortality forecasts by averaging the same model across multiple calibration periods. We propose and assess three different choices of the combination weights. In the first scheme, we generate the forecast combination using equal weights to average the individual forecasts; the second weighting method assigns heavier weights to predictions that use more recent data; and in the third approach, we propose an automated procedure to select diverse starting points to fit a mortality model and weights to combine the out-of-sample forecasts from the selected periods using linear regularization methods such as lasso regression. We illustrate our approach based on the GAPC mortality models. We apply our method to 19 male mortality data from the Human Mortality Database as the Lee-Carter model trend is non-linear and shows structural changes. In the out-of-sample forecast analysis, combining forecasts from multiple fitting periods produces a lower mean squared error of mortality rate forecasts than fitting the mortality models to the longest calibration period. For example, we show that the gain in the forecast accuracy of mortality rate forecasts combined based on the Age-Period-Cohort model relative to the longest fitting period is between 9.43% and 28.6% across forecast horizons for 19 male populations. This supports the model-fitting strategy of averaging mortality rate forecasts from multiple starting points for improving out-of-sample forecast performance. The results also show that the impact of selecting the historical period for fitting extrapolative mortality models can be greater than the choice of the mortality models that we considered.

Presenter Bio's:

Michael Sherris
Michael Sherris is a part time Professor in the School of Risk and Actuarial Studies having retired in 2016. His part time role concentrates on research, research student supervision and mentoring of early career researchers particularly through the ARC Centre of Excellence in Population Ageing Research where he is a Chief Investigator and Director of Industry Engagement. He was Head of Actuarial Studies at UNSW until 2010 having been appointed to UNSW in 1998 to establish the Actuarial Studies program. He is a Fellow of the Institute of Actuaries of Australia, the Institute of Actuaries (UK) and the Society of Actuaries (North America). His research focuses on longevity, health and functional disability risk modelling, long term care insurance and longevity risk management.

Francesco Ungolo
Francesco Ungolo earned a Master in Insurance and Risk Management from MIB School of Management discussing a thesis on Longevity Risk modelling under the supervision of Prof. Ermanno Pitacco in January 2015. Meanwhile, he worked for a year as Risk Management consultant where he was part of the model validation team for the calculation of Solvency II capital requirements. In September 2015 he joined Heriot-Watt University (Edinburgh, UK) to pursue the PhD program in Actuarial Mathematics under the supervision of Dr. Torsten Kleinow and Prof. Angus Macdonald, and the collaboration of Dr. Stephen Richards, completed in May 2019. From March 2019 to March 2021 he worked as Postdoctoral Researcher in Statistics at Technology University of Eindhoven (NL). He is currently a qualifying actuary for the Institute and Faculty of Actuaries UK. His expertise lies in the analysis and development of regression models for the analysis of complex actuarial datasets involving, among other things, cases of corrupted data, such as missing data for some lives, or the combined use of different datasets in order to return more robust estimates of mortality rates. Another key research theme is the analysis and the development of stochastic mortality models for the analysis of single and multiple populations, with a closer, albeit nonexclusive, focus on continuous time affine mortality models. The particular application lies within the analysis of individual savings and retirement

decision making with emphasis on the development of innovative product solutions using LTC, health, annuities and life insurance.

Andres Villegas
Andrés Villegas is a Senior Lecturer at the School of Risk and Actuarial Studies and an Associate Investigator at the ARC Centre of Excellence in Population Ageing Research (CEPAR) where he was previously a Research Fellow. Andrés completed his doctoral studies at Cass Business School in London focusing on the modelling and projection of mortality. Before his doctoral studies he obtained an MSc degree in Industrial Engineering from Universidad de Los Andes (Colombia) and worked as a risk analyst at one of the biggest Colombian life insurance companies. Andrés's research interests include mortality modelling, longevity risk management and the application of analytics techniques in actuarial science and finance.

Yawei Wang
Yawei Wang is a first year PhD student at UNSW. He is also a research assistant at the ARC Centre of Excellence in Population Ageing Research (CEPAR). His current research interest is retirement income products innovation.

David Bell
David Bell is the executive director of The Conexus Institute and an active researcher (industry and academic) in the areas of retirement, superannuation, investment management and governance. David recently completed his PhD at UNSW, with a focus on asset allocation problems related to lifecycle modelling. David's industry career experiences include the role of CIO at Mine Super, founder and director of his own consulting firm (St Davids Rd Advisory) and 12 years at CFS GAM (now First Sentier), mainly leading the fund-of-hedge funds investment team. David led the development of MDUF (the Member's Default Utility Function), was a co-founder of financial newsletter Cuffelinks, and developed and taught the hedge funds elective at Macquarie University's Applied Finance Centre.

Estelle Liu
Estelle is the Actuarial Practice Lead at Aware Super and her work includes superannuation projections, retirement modelling, policy submissions, defined benefits and member data driven insights and research. Estelle is a Fellow of the Institute of Actuaries of Australia (FIAA) and a Chartered Enterprise Risk Actuary (CERA). Estelle is the chair of the Actuaries Institute's Superannuation Projection and Disclosure Sub-committee, a member of the Superannuation and Investments Practice Committee and Data Analytics Practice Committee. Estelle won the Actuaries Institute Young Volunteer Achievement Awards in 2021. Estelle holds a Bachelor of Commerce with a first-class Honours in Actuarial Studies at UNSW Australia.

Victor Huang
Victor Huang is a principal with Milliman and heads up the Investment Solutions team in Australia. He has been with Milliman since 2008. Victor currently leads a team of portfolio managers, actuaries, and traders who design and implement investment strategies within superannuation, (re) insurance companies, ETF managers, and managed accounts. Strategies Victor has worked on include tail risk hedging, currency hedging, and rebalancing overlays for funds, as well as dynamic hedging programs for investment guarantee products and defined benefit liabilities.

Kyu Park
Kyu is a Senior Research Associate in the Risk and Actuarial Studies Department at the University of New South Wales, working for the Australian Research Council (ARC) Centre of Excellence in Population Ageing Research (CEPAR). He is working on research projects in the Sustainable Wellbeing in Later Life research stream, focusing on the development of longevity and health risk models and optimal design of health and aged care insurance products with applications to various public sector support policies for retirement incomes and aged care. He recently completed a PhD in Actuarial Studies and Business Analytics at Macquarie University for his work on analysis to find causes and outcomes of medication adherence in aged population.

Len Patrick Garces
Len Patrick Garces is a Senior Research Associate at CEPAR, UNSW Sydney. His current work investigates continuous-time stochastic mortality modelling and the design and valuation of variable annuities. More generally, his research interests are focused on understanding longevity and mortality risks and how these risks interact with actuarial and insurance valuation. In terms of methodology, Len is interested in the applications of probability theory and stochastic analysis to financial and actuarial issues. Len obtained his PhD from the University of South Australia with a thesis on the use of stochastic volatility and jump-diffusion models and formulating corresponding numerical methods for option pricing. He received a BSc in Applied Mathematics, a BA in Economics, and a Master's degree in Applied Mathematics from Ateneo de Manila University in the Philippines.

Michelle Vhudzijena

Michelle is a PhD student in the School of Risk and Actuarial Studies at the University of New South Wales. She graduated from Harvard University in 2012 with a Bachelor of Arts in Biomedical Engineering. Before her doctoral studies, she worked as an actuarial consultant and biomedical engineering researcher. Her research interests include mortality modelling using multiple health and socio-economic risk factors, cause of death mortality modelling, long term care, predictive models, and survival analysis. Most of her work involves unsupervised learning and analysis of individual–level longitudinal data.

Salvatory Kessy

Salvatory Kessy is a final-year Ph.D. student in the department of Risk and Actuarial Studies at the University of New South Wales. He holds a Master of Science in Actuarial Science from the University of Southampton and a Bachelor of Science in Actuarial Science from the University of Dar-es-Salaam. Kessy has also completed eight Core Technical (CTs) Actuarial Professional Exams offered by the Institute and Faculty of Actuaries UK (IFOA). His research is at the frontier of statistical machine learning and actuarial sciences. He aims to apply advanced data analytics techniques to population and individual level data to increase the prediction accuracy of the mortality rates.