



# Australasian Actuarial Education and Research Symposium 2023

23–24 November  
Victoria University of Wellington  
Wellington, New Zealand

## Presenters and Abstracts

Plenary and Invited Sessions are listed first,  
in sequential order

Contributed Presentations follow,  
ordered alphabetically by  
presenters' last names

Editor: **John Haywood**

**Plenary Session 1, 23 November**  
***What is disaster insurance good for?***  
***Can it be improved?***

**Ilan Noy**

Victoria University of Wellington

In *King Lear*, Shakespeare observed that “we make guilty of our disasters the sun, the moon, and stars, as if we were villains on necessity.” After the Canterbury earthquake sequence of 2010-2012 the majority of Cantabrians’ primary cause of stress was their need to deal with insurance. It was not ‘the moon, the sun and the stars’, nor the repeating movement of the tectonic plates under their feet. In this talk we will make ten observations on what may have gone wrong in Christchurch in the aftermath of the earthquakes. By focussing on these observations we can improve our disaster insurance systems. This is critical, as both the frequencies and intensities of some types of extreme weather events are increasing because of anthropogenic climate change.

**Plenary Session 2, 23 November**  
***The COVID-19 Wage Subsidy and the role of actuaries***

**Wayne Anderson and John Gibbs**

New Zealand Ministry of Social Development—Te Manatū Whakahiato Ora  
Joint work with Yan Chen

New Zealand’s COVID-19 Wage Subsidies were one of the key supports to employers and employees during the COVID-19 lock-downs and higher alert levels. These provided over \$15b to support employers retain their employees during the pandemic, and ensured their employees had incomes. This talk will discuss:

- What was the wage subsidy, and why did it matter?
- What we did to help understand who was receiving support?
- Why actuaries were involved?

**Invited Session, 23 November**  
***Earthquakes and tsunami hazards in New Zealand:***  
***A geophysical perspective***

**John Townend and Laura Hughes**

Te Herenga Waka—Victoria University of Wellington

New Zealand sits on the boundary between the Australian and Pacific tectonic plates and is exposed to a wide variety of geohazards including earthquakes, tsunami, landslides, and volcanic eruptions. Recent earthquakes and tsunami in New Zealand and elsewhere, notably the 2009–2011 Canterbury sequence, the 2004 Sumatra and 2011 Tōhoku earthquakes and tsunami, and the 2016 Kaikōura earthquake, have highlighted both the scale of the hazards these perils present to New Zealand and their complexity. A particular challenge is to reconcile scientific knowledge of processes operating on millennial timescales with the decadal timescales relevant to political and socioeconomic decision-making, and to fully account for uncertainties in hazard forecasts. In this presentation, Professor of Geophysics John Townend and PhD student Laura Hughes will summarise recent work to quantify the rates and effects of future geohazards using innovative observational and computational techniques in earthquake and tsunami science.

**Plenary Session 3, 24 November**  
*Broadening horizons – The evolving role  
of actuaries in the public sector*

**Alan Greenfield**  
Taylor Fry

Actuaries have a long history of working in the public sector. This has mainly involved performing traditional actuarial roles. Over the last 10-20 years actuaries have applied their skillset to a broadening range of government policy and service considerations. Ever increasing computational capacity and access to broader data has seen an explosion in data science and a blurring of the lines between actuaries and data scientists. In this session, Alan Greenfield will present three social sector case studies, demonstrating wide applicability of actuarial skills and providing insight into how the actuarial community can broaden its horizons.

**Plenary Session 4, 24 November**  
*Portfolio optimization with wealth-dependent risk constraints*

**Rudi Zagst**  
Technical University of Munich  
Joint work with Marcos Escobar-Anel, Markus Wahl

Regulatory risk constraints as in the European Solvency II standard formula for insurance companies may lead to wealth-dependent constraints on the investment strategy. We develop two solution approaches for portfolio optimization problems in continuous time with wealth-dependent constraint sets. In the first approach, we reduce the optimization problem to an associate problem with constraints independent of wealth and a different utility function. The associate problem is then solved using known convex duality results. In the second approach, we use a change of control. We apply these results to Solvency II constraint sets and find that even for an investor with HARA utility who inherently reduces risk in times of distress, the constraints help to prevent the investor from taking too much risk in an optimistic market. Furthermore, we measure significant loss in utility and reduction in risk caused by the constraints, and we also evaluate the trade-off between these two effects.

**Plenary Session 5, 24 November**  
*Lifelong learning*

**Mike Callan**  
Actuaries Institute Executive General Manager (Education)

Professions require members to continue to study throughout their professional lives. This study is often a mixture of formal and informal courses, attendance at conferences, keeping abreast of relevant legislative, social and regulatory changes. Some components are technical whereas other components are the so-called ‘soft-skills’. This presentation is an introduction to the professional actuarial model that relies on examination and post-qualification experience as set out in Pegler’s 1968 Presidential Address to the Institute of Actuaries. We will explore how the Actuaries Institute can assist its members to wade through the ever increasing amount of knowledge.

*A strategy for Actuarial Research — for the profession  
and universities*

Anthony Asher, UNSW

**24 November, Session C1, Presentation 3**

The field of actuarial studies was a late comer to university education, and there is little integration of research between the profession and the universities. While attracting a significant share of academically excellent students, few go on to higher research degrees. The economic sectors in which actuaries work also account for a disproportionately small share of national research expenditure. One question to ask is whether this disproportionality is appropriate and how it might be addressed by the profession and the universities collaboratively. Suggestions include making the following needs more salient among decision makers:

- Increasing the collection of relevant data and making it available for academic research
- Encouraging more local research by developing a high quality local academic journal
- Encouraging more higher degree research students not least by ensuring that the marks allocated to actuarial students give them a fair share of scholarships
- Developing an actuarial Wiki to provide for more knowledge sharing for educational and research purposes
- Encouraging a greater focus on funding for research.

*Diversification of infinite-mean Pareto risks*

Yuyu Chen, University of Melbourne

Joint work with Paul Embrechts, Ruodu Wang

**23 November, Session B2, Presentation 3**

We show the perhaps surprising inequality that the weighted average of i.i.d. extremely heavy-tailed (i.e., infinite mean) Pareto losses is larger than a standalone loss in the sense of first-order stochastic dominance. This result is further generalized to Pareto risks in the context of negative dependence, convex transformations, random summation and weights, and losses triggered by catastrophic events. We discuss several implications of these results via an equilibrium analysis in a risk exchange market. First, diversification of extremely heavy-tailed Pareto losses increases portfolio risk, and thus a diversification penalty exists. Second, agents with extremely heavy-tailed Pareto losses will not share risks in a market equilibrium. Third, transferring losses from agents bearing Pareto losses to external parties without any losses may arrive at an equilibrium which benefits every party involved. The empirical studies show that our new inequality can be observed empirically for real datasets that fit well with extremely heavy tails.

*Insurance pricing under joint extremes*

Zhen Dong Chen, UNSW

Joint work with Peiman Asadi, Qihe Tang

**23 November, Session B2, Presentation 1**

The compounding impact of extreme rainfall and heavy winds can lead to devastating disasters, such as floods. This paper presents a novel approach to modeling the joint extremes of precipitation and wind speed. A case study is conducted using time series data from weather observatories across NSW, Australia. Challenges arise when applying the peaks-over-threshold analysis to a substantial number of datasets. To address these challenges, we develop an automatic threshold selection method and an automatic declustering technique. Furthermore, we introduce a proxy based on these joint extremes and create a heatmap to identify any significant trends. This proxy has the potential to provide valuable insights for pricing climate risk within the insurance context.

*Valuing an arithmetic Asian option with  
Artificial Neural Network method*

Erwinna Chendra, Parahyangan Catholic University

Joint work with Christian Jauhari, Andreas Parama Wijaya

**24 November, Session C2, Presentation 3**

Pricing an Asian option with an arithmetic average is interesting because there is no analytical solution. Usually, pricing such options uses numerical methods, one of which is the Monte Carlo method. This method's weakness is the computation time length because it must generate many trajectories of asset price movements. This paper uses a data-driven approach through the Artificial Neural Network (ANN) method that can speed up computation time. The ANN method requires input and target data sets from Lévy's approximation solution, Monte Carlo with antithetic variables, and Quasi-Monte Carlo. The ANN method learns the data from these three data sets to form each model that can accept the input of option parameters to determine the price. The most crucial thing in ANN models is the model architecture, such as assessing the number of neurons, layers, and the use of activation functions. This paper presents several simulations to determine the best model architecture based on the smallest Mean Squared Error (MSE). In addition, the evaluation of the three ANN models that have been built shows that each model is optimal based on the smallest MSE and a coefficient of determination close to one. This paper also shows that option pricing using the ANN method is more efficient than the Monte Carlo method.

*Cumulative Parisian ruin in finite and infinite  
time horizons in a renewal risk process*

**Eric Cheung**, UNSW

Joint work with Wei Zhu

**23 November, Session A2, Presentation 1**

In this presentation, we consider the cumulative Parisian ruin problem in a renewal risk model with general interclaim times and exponential claims, where the cumulative Parisian ruin time is the first time the total time spent by the surplus process below level zero exceeds a certain time length. The infinite-time cumulative Parisian ruin probabilities are derived under a deterministic Parisian clock and under an Erlang clock, where the latter case can also serve as an approximation of the former. The finite-time cumulative Parisian ruin probability is subsequently analyzed when the time horizon is another Erlang random variable. Our formulas can be easily applied in numerical examples where the interclaim times follow gamma, Weibull, or Pareto distributions. We demonstrate that the choice of the interclaim distribution does have a significant impact on the cumulative Parisian ruin probabilities when one deviates from the exponential assumption.

*Optimal retirement wealth*

**Toby Daghli**, Victoria University of Wellington

Joint work with Ting-Way (William) Hsiao

**23 November, Session A3, Presentation 4**

We develop a model for an investor with Duffie-Epstein preferences choosing to retire from a constant income job. The retired investor receives greater leisure time which may compensate for the loss of income. We establish a trinomial tree approach to solve this American option style problem. We demonstrate that this approach is superior to existing techniques from the literature. Lastly, we examine some numerical examples of investors making the retirement decision. Advice from the model are realistic. We provide comparative statics, demonstrating the importance of return dynamics, preferences, and income on the retirement decision.

*Pricing carbon emission permits under the  
cap-and-trade policy with uncertainty*

Ryan Dai, UNSW

Joint work with Henry Lam, Qihe Tang

**23 November, Session A1, Presentation 1**

Government policies are generally considered the most powerful and efficient tools for climate mitigation. In this paper, we explore a cap-and-trade framework in which the total amount of carbon emissions is limited by a government-imposed cap. We determine the carbon price through a competitive trading market involving both green and brown sectors. To achieve this, we develop a dynamic stochastic general equilibrium model in which energy input serves as a proxy for integrating carbon emissions into the production process. We calculate the optimal carbon price by examining the social planner's problem from a top-down perspective and the sectors' maximization problems from a bottom-up perspective, respectively. Risk aversion and uncertainty are incorporated to ensure the robustness of our results.

*Distributional forecasting via an interpretable  
actuarial neural network*

Eric Dong, UNSW

Joint work with Benjamin Avanzi, Patrick Laub, Bernard Wong

**24 November, Session C2, Presentation 1**

Neural networks have recently seen extensive developments in the actuarial field (Richman, 2022). Adapting neural network technology to actuarial science can be difficult as we place high importance on interpretability and distributional forecasting. Existing approaches include the Combined Actuarial Neural Network (Schelldorfer and Wuthrich, 2019) and the Mixture Density Network (DeLong et al., 2021, Al-Mudafer et al., 2022). However, these architectures rely on prespecified distributional assumptions. These assumptions may not be appropriate and can impact the ability to quantify the variability of outcomes accurately and undermine the reliability of the distributional forecasts. This paper presents a new neural network architecture that allows for distributional flexibility and a level of interpretability; these are typically two conflicting objectives. The predictive performance and forecasting interpretability of our architecture are demonstrated on both synthetic and real actuarial datasets.

*Understanding compound weather and climate events  
through the lens of systemic financial crises*

Eugenia Fang, UNSW

**23 November, Session B1, Presentation 1**

Climate change has emerged as one of the greatest global challenges of our time. One of the most concerning risks of climate change is the potential for compound events (CEs) to increase, where multiple climate drivers and/or hazards interact with each other in a complex manner, leading to amplified impacts on the physical environment, human systems, and ecosystems. To achieve a quantitative understanding of CEs, we develop a modeling framework that comprises climate drivers, hazard events, and damages and addresses the stochastic nature of CEs. Motivated by recent studies on complex financial networks and the long-standing concept of systemic risk, we liken CEs to systemic crises in complex financial networks. Despite apparent differences between the two concepts, CEs, and financial crises share strong similarities. CEs are influenced by climate change, which, in turn, is caused by carbon emissions. Similarly, financial crises are driven by factors like excessive risk-taking, macroeconomic imbalances, and regulatory failures, all of which can be traced back to human greed. Therefore, some of their similarities may be attributed to their common anthropogenic nature. The fully stochastic and dynamic nature of our modeling framework makes it feasible to accommodate some important features of CEs, such as spatio-temporal dependencies, causal chains, feedback loops, tipping points, nonlinearity, and deep uncertainty.

*Robustness of the Higher Moment risk measure:  
embracing qualitative and quantitative aspects*

Fabio Gomez, UNSW

Joint work with Jose Blanchet, Spiridon Penev, Qihe Tang

**23 November, Session A2, Presentation 2**

The Higher Moment (HM) risk measure offers a broader perspective on risk assessment, encompassing expected shortfall and accommodating a risk aversion parameter. This study delves into several robustness considerations associated with the HM risk measure. Our analysis establishes the robustness of the HM risk measure against optimization, aligning with the recent framework proposed by Embrechts, Schied and Wang (2022, *Operations Research*). Building upon the HM risk measure, we delve into distributionally robust optimization for linear portfolios. Moreover, we revisit the domains of risk parity and capital allocation under ambiguity, leveraging the Wasserstein distance to quantify such ambiguity.



*Hedging volume and price risks  
in wind energy production*

**Giovani Gracianti**, University of Melbourne  
Joint work with Rui Zhou, Xueyuan Wu, Johnny Li  
**23 November, Session A1, Presentation 2**

Revenue uncertainties for wind energy producers arise from two primary sources: fluctuations in the volume of energy produced and in the energy price. While most existing studies address only one of these risks, our research holistically tackles both. By considering both power futures and wind derivatives as hedging instruments, we aim to develop comprehensive risk-mitigation strategies. Our initial step involves modelling the dynamics of electricity prices and wind energy production across multiple regions. This model adeptly captures the relationship between energy prices and wind production volumes, as well as the dependence of energy production across different locales. Building on this foundation, we design hedging portfolios that aim to minimize revenue volatility. Preliminary findings suggest that a balanced approach, which combines both power futures and wind derivatives, can significantly reduce income volatility as compared to singular derivative product strategies. Furthermore, our research examines how the geographical distribution of wind energy capacities can impact revenue fluctuations and the efficacy of our hedging strategies.

*Insurance price cycles: insurer's preferences  
and policyholders' welfare*

**Hamza Hanbali**, Monash University  
Joint work with Dan Zhu, Jackie Li  
**24 November, Session C1, Presentation 1**

Insurance premiums typically exhibit a cyclical behaviour over time. This phenomenon is well-documented in the literature, and has been reported in many business lines and in many countries, with a cycle length between 5 and 6 years. The aim of the present paper is to study the impact of premium cyclical on both the provider and policyholders. Using econometric techniques, the impact of cyclical is studied by constructing a synthetic counter-factual where premiums are non-cyclical, and analysing the distribution of the accumulated losses under the cyclical and non-cyclical models over a planning horizon corresponding to the length of the underwriting cycle.

*Expanding the Income Contingent Loan (ICL)  
to women with partner violence*

**Lucy Yunxi Hu**, Australian National University  
Joint work with Timothy Higgins, Jananie William  
**24 November, Session D1, Presentation 2**

The aim of this thesis is to develop models for the design and costing of Income Contingent Loans (ICLs) with specific applications to women experiencing partner violence (PV). ICL is primarily used in the higher education system, offering benefits such as consumption smoothing and default protection. Our research makes several contributions to the existing literature by incorporating advanced labour force models, novel methods for projecting lifetime income and exploring the application of ICL in new domains.

In this presentation, I will discuss the expansion of ICL to women experiencing PV in Australia, with an emphasis on modelling the dynamics of labour force (LF) outcomes. 17% of Australian women have ever experienced PV in their lifetimes, and there are currently limited financial resources available to women who experience PV, highlighting the need to consider different mechanisms of financial support. I present a model for labour force dynamics and use HILDA data to conduct a comparison between two candidate models. We find that experiencing PV significantly impacts women's labour force transitions only in the short run and shows no significant effect over the long-run horizon. The presentation will conclude with a discussion on potential limitations and avenues for future research.

*Delegated investment in retirement  
savings: value add?*

**Tiancheng Huang**, Australian National University  
Joint work with Gaurav Khemka, Alfred Chong  
**23 November, Session A3, Presentation 1**

We study a discrete-time life-cycle retirement planning problem for individual workers with three distinct investment options: Self-Management (SM), Hire-Management (HM), and Benchmark-Management (BM). We examine the investment strategies and consumption patterns during the Defined Contribution fund accumulation period, ending with a life annuity purchase at retirement to finance post-retirement consumption. Based on the calibrated model (using US data), we employ numerical dynamic programming techniques, including the method of endogenous gridpoints and the value function iteration, to optimize worker's financial decisions. Our analyses reveal that delegated investment can add value to a worker's lifetime utility if the fund manager has a broader constraint on short-selling and borrowing. However, after taking the US fund fee data into consideration, we find that the HM option may not be a value-add compared to the SM option, but it still outperforms the BM option.

## *Epidemic modelling and pandemic insurance*

**Zhuo Jin**, Macquarie University

Joint work with Ken Siu, Ping Chen, Chang Zhai

**24 November, Session D1, Presentation 3**

With the recent outbreak of COVID-19, evaluating the epidemic risk appears to be a pressing issue of global concern and one of the major challenges recently. In the fight against pandemics, the ability to understand, model, and forecast the transmission dynamics of infectious diseases plays a crucial role. This paper provides an overview of foundational compartment models and introduces the SVEI3RD model to study the dynamics of COVID-19. A meticulous data calibration procedure is employed to study the evolution trend of an actual pandemic using real-world data from Victoria, Australia. Additionally, the paper discusses innovative applications of epidemic models to the insurance industry, which are currently under investigation. Through the use of the newly developed analytically tractable model, insurance companies are able to determine fair premium levels during an outbreak. Moreover, the paper provides practical guidance for insurance companies by examining the variation in reserve levels over time.

## *Building a student community to supercharge peer feedback*

**Poon Leung**, UNSW

**24 November, Session C1, Presentation 2**

A sense of belonging and community is a vital part of the student experience. Regrettably, these elements are often seen as supplementary or tangential to the core academic curriculum. In my data visualisation course at UNSW, I have instead integrated belonging and community explicitly into the core of this course. The course creates a collaborative environment for students, and leverages this to scaffold assignments using peer feedback. Students actively share drafts of their work into this collaborative environment and bounce ideas off each other, which also has the convenient side-effect of reducing the burden on the convenor. The benefits of this process are immediately visible. Students are actively engaged both in-person and online. The quality of students' work is clearly improving over the term, and more importantly they are consciously aware of this. The numbers also back this up. A survey conducted at the end of the course had a high response rate, and overwhelmingly positive feedback. In this talk, I will share how I achieved this in my course, my plans moving forward, and some tips I have for anyone considering implementing these ideas in their own courses.

*Alternative data usage in life and health insurance*

**Han Li and Zhan Wang,**

University of Melbourne and Azuria Partners, Sydney

**24 November, Session C1, Presentation 4**

This is an SOA funded research initiative aiming to establish a framework for evaluating the effectiveness of various alternative datasets for life and health insurance. The research adopts a collaborative approach and invites market participants to interviews to discuss considerations in applying the framework to actuarial practice. The research has identified a few real-world examples and we include them as case studies.

*Fast estimation of the Renshaw-Haberman model and its variants*

**Johnny Li,** The Chinese University of Hong Kong

Joint work with Yiping Guo

**24 November, Session D3, Presentation 3**

In mortality modelling, cohort effects are often taken into consideration as they add insights about variations in mortality across different generations. Statistically speaking, models such as the Renshaw-Haberman model may provide a better fit to historical data compared to their counterparts that incorporate no cohort effects. However, when such models are estimated using an iterative maximum likelihood method in which parameters are updated one at a time, convergence is typically slow and may not even be reached within a reasonably established maximum number of iterations. Among others, the slow convergence problem hinders the study of parameter uncertainty through bootstrapping methods. In this paper, we propose an intuitive estimation method that minimizes the sum of squared errors between actual and fitted log central death rates. The complications arising from the incorporation of cohort effects are overcome by formulating part of the optimization as a principal component analysis with missing values. Using mortality data from England and Wales and United States, we demonstrate that our proposed method produces satisfactory estimation results and is significantly more efficient compared to the traditional likelihood-based approach.

***Forecasting private health insurance participation  
in Australia: a microsimulation model***

**Qingyue Li**, Australian National University

Joint work with Timothy Higgins, Wai-Man Liu, Aaron Bruhn

**24 November, Session D1, Presentation 1**

Australia's Private Health Insurance (PHI) industry faces the persistent challenge of the adverse selection spiral, primarily attributable to community rating. This study endeavours to project the future of PHI participation in the years to come through the development of a microsimulation model tailored to the Australian context. To construct this model, we start with the 2016 Australian Census 1% sample as a foundational dataset. Subsequently, we employ a stochastic microsimulation approach to predict individual decisions pertaining to PHI, utilizing data from the Household, Income and Labour Dynamics in Australia (HILDA) Survey to develop dynamic models of PHI decisions. The microsimulation model is structured into five distinct modules, addressing demographics, marital dynamics, education, income, and PHI-related choices. Our analysis also encompasses sensitivity tests for specific parameters. Our findings portray a consistent decline in the overall PHI participation rate over the forecasted years. Furthermore, there is a noteworthy increase in the proportion of the elderly population (ages exceeding 65) within the insured demographic. We also report on how different assumptions of future wage inflation and Medicare Levy Surcharge thresholds affect participation. This research extends beyond the realm of predicting PHI participation rates; it offers a systematic framework for evaluating the evolving characteristics of the insured population. Additionally, the model provides the means to assess the impacts of different government policy scenarios on participation rates. Our ongoing research also explores the effect of premium adjustments caused by shifting age demographics within the insured cohort.

***Utility indifference pricing of green bonds***

**Yuhao Liu**, UNSW

**23 November, Session A1, Presentation 3**

The green bond market was born in 2007, started to accelerate from 2014, and has reached US\$2.334 trillion globally as of June 2023. Green bonds, as an innovative financial instrument, have played an important role in capital mobilization towards climate change mitigation and adaptation. This study aims at the pricing of a single-period defaultable green bond. Main challenges of the pricing task include the following: First, the prices of financial assets are significantly influenced by the financial risks induced by climate change; Second, and more importantly, investors may derive non-pecuniary benefits from green asset investments, as revealed by empirical research on Environment, Social and Governance (ESG) investing. We develop a utility indifference pricing framework that encapsulates both the climate-related financial risks and the non-pecuniary benefits from green investments. This framework provides a probabilistic representation of the utility indifference price of the bond. Moreover, we conduct extensive numerical analyses to examine the effects of the climate risk and non-pecuniary benefits on the price.

***Postcode-Level reverse mortgages: longevity risks,  
house price risks, and welfare gain***

**Lingfeng Lyu**, Risk and Actuarial, UNSW;  
ARC Centre of Excellence in Population Ageing Research  
Joint work with Michael Sherris, Jonathan Ziveyi, Yang Shen

**23 November, Session A3, Presentation 2**

This research evaluates the Home Equity Access Scheme (HEAS) versus downsizing for older Australians, factoring in elements such as means tests, health expenditures, taxes, and home maintenance. It builds on a utility approach, considering region-specific house price and longevity risks. Findings reveal that HEAS enhances healthy aging for healthy and mildly disabled retirees more than downsizing. This scheme benefits cash-poor but asset-rich retirees who have lower bequest motives, derive higher satisfaction from spacious homes, and prioritise long-term gratification. However, spatial disparities in housing prices and life expectancy decrease the uptake of HEAS, offering new perspectives on housing decisions among seniors in Australia.

***Cyber risk taxonomies: statistical analysis of  
operational cybersecurity risk classifications***

**Matteo Malavasi**, UNSW

Joint work with Pavel Shevchenko, Stefan Trueck,  
Jiwook Jang, Georgy Sofronov, Gareth Peters

**24 November, Session D2, Presentation 3**

Cyber risk classifications map cyber threats to cyber risk types, allowing for cyber loss modelling and quantification. There exist a growing number of cyber risk classifications, each designed with specific intent, purpose, and which build on pre-existing laws and policies. In this paper we analyse the most commonly used classifications and argue in favour of switching the attention from goodness of fit and in-sample predictive performance, to focusing on out-of-sample forecasting performance in evaluating cyber risk classifications. We adopt the maximising sharpness of the predictive distribution subject of calibration paradigm and evaluate the forecasting performance of cyber risk classifications via various threshold weighted scoring rules. Our results suggest that business motivated cyber risk classification appears to be too restrictive and not flexible enough to capture the heterogeneity of cyber risk events. Moreover, we investigate how dynamic cyber risk classifications based on risk metric evaluation, seem to be better suited in forecasting future cyber risk losses than the other considered classifications. Our study provides insights on the classification of cyber risks useful for both decision and policy makers, and it contributes to the scientific literature on cyber risk.

*Extreme value analysis of investment losses  
coupled with exogenous shocks*

Xinyue Man, Central South University, China;  
University of New South Wales  
Joint work with Qihe Tang

**23 November, Session B2, Presentation 2**

Consider a company who undertakes a risky project that carries the potential for investment losses and is additionally vulnerable to exogenous shocks. These unpredictable shocks pose challenges for both the company and the regulator in accurately foreseeing their impact, potentially leading to an underestimation of the solvency capital when employing traditional approaches. In this paper, we utilize a stylized model to conduct an extreme value analysis of such a risky project under various extreme scenarios, aiming to gain a quantitative understanding of the role of exogenous shocks in driving possible catastrophic losses. As an application, we derive asymptotic estimates for the value at risk and expected shortfall of the total loss from the risky project. Furthermore, we conduct extensive numerical studies to examine the accuracy of the obtained approximations.

*The dynamics and interactions of the  
building blocks for retirement income*

Shams Mehry, Australian National University  
Joint work with Adam Butt, Gaurav Khemka

**23 November, Session A3, Presentation 3**

The worldwide shift away from defined benefit pensions towards defined contribution (DC) pensions is causing a transfer of investment and longevity risk from pension providers onto retirees, given DC pensions do not provide guarantees on what payments retirees can expect to receive. Hence, effective retirement income planning is crucial to ensure that assets accrued over one's working life are sufficient in providing reasonable income in one's retirement. This paper seeks to break down the retirement income planning problem from the perspective of four building blocks: mortality credits, investment strategies, drawdown schedules, and pension income. Utilising this breakdown, the paper will explain how each of these building blocks interact to form a retiree's overall retirement income portfolio, and what trade-offs exist between these building blocks that the retiree must consider. We consider a retiree's behaviour under a power utility framework and allow them to invest their wealth in three structures: one offering deterministic mortality credits, one offering stochastic mortality credits, and an account-based pension which does not offer mortality credits, but does offer complete flexibility in drawdowns. The retiree can choose an investment strategy across a risky and risk-free asset, and can utilise a self-financing options trading strategy to smooth their investment returns. This retirement income planning problem is analysed under three different pension systems: no pension, a fixed pension, and a means-tested pension. The results of this analysis highlight the contribution of each building block towards a retiree's consumption through retirement, along with what interactions and trade-offs they present.

*Developing private long-term care insurance in Australia:  
Pricing analysis for healthy and chronically ill Australians*

Kyu Park, UNSW

ARC Centre of Excellence in Population Ageing Research

Joint work with Michael Sherris

**24 November, Session C3, Presentation 4**

To establish a private long-term care insurance (LTCI) market in Australia, calculating LTCI product costs requires a reliable actuarial model suited to the local population. Utilising our existing five-state Markov model on functional disability and chronic illness, we estimated premiums for LTCI products, encompassing stand-alone LTCI and life care annuity (LCA), and assessed the impact of these products on an individual's utility. The model considered factors including age, sex, and (optionally) trend, utilising Australian data from 1998 to 2018. For product design and assumptions, we factored in the comfortable consumption level and aged pension for Australian retirees, and insights gained from our systematic literature review on LTCI pricing methods and outcomes. The calculated premiums include expected benefit payments and the Solvency II capital requirement (SCR). We performed sensitivity analysis on utility measures based on assumptions about individual traits. The stand-alone LTCI was devised to provide a \$1,500 monthly disability benefit, capped at \$7,600 over a lifetime. The LCA combined a \$1,000 monthly annuity payment with the stand-alone LTCI. Premiums showed considerable variation based on retirement illness status, and whether trend factors were incorporated. Estimated stand-alone LTCI premiums comprised 16% to 27% of SCR, while LCA premiums ranged from 7% to 11% of SCR. In many cases, purchasing an LTCI product increased individual's utility, though the degree relied on factors like risk aversion and wealth level. The creation of an Australian private LTCI market requires meticulous attention to population demographics, aging trends, and individual traits.

*Beyond linearity: a Bayesian nonparametric  
VAR approach to mortality modelling*

Jianjie Shi, Monash University

Joint work with Yunyun Wang

**24 November, Session C3, Presentation 1**

This study introduces a novel nonparametric approach to mortality modelling, addressing the limitations of traditional Vector Autoregressive (VAR) models. Although VAR models are prevalent, their inherent assumption of linearity between endogenous variables and their lags can sometimes be restrictive. This limitation becomes particularly evident when dealing with extreme observations, such as those arising from the COVID-19 pandemic. To address these challenges, we introduce the Bayesian Additive Vector Autoregressive Tree (BAVART) model into mortality modelling. This innovative model, a fusion of VAR and Bayesian additive regression tree (BART) techniques, provides a flexible framework capable of capturing intricate nonlinear relationships. Furthermore, we incorporate a sparsity-inducing Dirichlet hyperprior on the tree's splitting proportions, enhancing adaptability to sparsity in the BAVART model. Our empirical analysis, drawing from mortality datasets across multiple countries, highlights the BAVART model's proficiency in accurately capturing these dynamics. Owing to its flexibility and precision, the BAVART model stands as a promising tool for future mortality modelling research and related fields.



*Parisian excursion with capital injection for  
drawdown reflected Lévy insurance risk process*

**Budhi Surya**, Victoria University of Wellington

Joint work with Wenyuan Wang, Xianghua Zhao, Xiaowen Zhou

**24 November, Session A2, Presentation 3**

In this talk I will discuss Parisian ruin problem under drawdown with capital injection when the underlying source of randomness of the surplus is modeled by a general Lévy insurance risk process. The capital injection is provided at the first instance the surplus drops below the drawdown level which is a pre-specified function of its current maximum. The capital is continuously injected to keep the surplus above the drawdown level until either it goes above its current maximum or a Parisian-type ruin occurs, which is announced at the first time the surplus process has undergone an excursion below its current maximum for an independent exponential period of time consecutively since the most recent drawdown time. Some distributional identities concerning this excursion are presented. Firstly, the Parisian ruin probability and the joint Laplace transform (possibly killed at the first passage time above a fixed level for the surplus process) of the ruin time, the surplus position at ruin, and the total capital injection at ruin. Secondly, the  $q$ -potential measure of the surplus process killed at Parisian ruin. Finally, the expected present value of the total discounted capital injected up to the Parisian ruin time. The results are derived using recent developments in fluctuation and excursion theory of spectrally negative Lévy process and are presented semi-explicitly in terms of the scale function of the Lévy process. Some numerical examples are given to facilitate the analysis of the impact of initial surplus and frequency of observation periods to the ruin probability and to the expected total discounted capital injection.

*Flexibility and selection effects in modern tontines*

**Eugene Tan**, Australian National University

Joint work with Adam Butt, Gaurav Khemka

**23 November, Session B3, Presentation 1**

Due to the recent financial crisis and increased longevity, pension systems with guaranteed benefits are no longer sustainable. Therefore, there has been a significant shift from defined benefits pension schemes to defined contribution pension schemes, often without the same level of guarantees. In Australia, retirees tend to over-rely on account-based pensions (ABP) which are less efficient in converting superannuation assets to retirement incomes. Despite the active effort by the Australian government and the advantages of delivering a guaranteed income, annuity sales in the Australian market remain low. Weighing the immense pressure on Australia's retirement income system, there is increasing discussion on the merits of modern tontines in the Australian context and growing interest in the concept of mortality risk sharing. This paper examines the impact of heterogeneity in the tontine pool, the selection effects exhibited by the pool members and the choices made by the model policyholder when flexibility such as investment options and variable drawdown amounts are introduced. To examine each of them separately, we are able to isolate the effects on the mortality credits received by the model policyholder, caused by the pool heterogeneity and selection effects from the underlying mortality risk. Furthermore, we are able to identify and study the sources of variability in the regular tontine payments received by a member. As such, this gives us the opportunity to compare and contrast the effect of various pool heterogeneity, selection effects and choices made by the model policyholder.

*Analysing reporting patterns and frequency of data breaches  
published by state Attorneys General in the United States*

**Xingyun Tan**, University of Melbourne

Joint work with Benjamin Avanzi, Greg Taylor, Bernard Wong

**24 November, Session D2, Presentation 2**

We study data breach notifications and investigate breach frequency by state and severity of the breach in the United States. We identify how breaches are notified over time, and discuss how to project breaches that have incurred but have not been reported yet. We utilise a set of public data provided by state Attorneys General that contains dates of occurrence and recent breaches, which are not included in the most widely used public dataset provided by the Privacy Rights Clearinghouse (PRC). We introduce this data set and compare it with the PRC dataset for cyber researchers to understand their disparities and better use these resources to obtain cyber insurance insights. We implement a new event definition that provides insight into the true impact of data breaches and allows for managing cyber insurance at portfolio level. Our analysis provides important insights. The reporting patterns vary significantly across different time periods and breach sizes, and the average delay between occurrence and reporting has increased across states. The data breach frequency is relatively stable before 2020 but increases subsequently across states. Although the reporting patterns vary across states, states exhibit similarities in frequency trends, the timing of change in reporting patterns, and trends in the average delay.

*Valuing equity-linked insurance products for couples*

**Kelvin Tang**, UNSW

Joint work with Eric Cheung, Jae Kyung Woo

**24 November, Session C3, Presentation 2**

In the pricing of joint life contracts, it is often convenient to assume that the lifetimes of different persons are independent. However, some results in the literature have demonstrated that the lifetimes of a couple typically exhibit positive dependence, and failure to account for this dependence can lead to significant mispricing of benefits. In this presentation, we explore the valuation of some equity-linked products for a couple under the assumption that the lifetimes can be dependent. While traditional equity-linked products are usually only defined for a single life, we propose some products designed specifically for a couple where the benefit can depend on the death times of both lives. These include, for example, a reversionary annuity that pays the surviving spouse until his/her death, where the payment can depend on an underlying equity index which helps to guarantee the standard of living for the surviving spouse. By modelling the joint mortality function with a bivariate mixed Erlang distribution, our model generalises some existing results in the literature and finds closed-form solutions for the expected value of the products. In principle, our results can also be generalised to model multiple dependent events.

*Shapley decomposition-based selection of representative contracts  
for variable annuity portfolio valuation*

Gayani Thalagoda, UNSW

Joint work with Katja Hanewald, Andrés M. Villegas, Jonathan Ziveyi

**24 November, Session C3, Presentation 3**

The paper presents a Shapley decomposition-based method to enhance explainability in the selection of cluster representatives for valuing variable annuity portfolios. While existing clustering-oriented data mining frameworks offer notable reductions in computational time, the selection of cluster representatives using these methods is independent of the risk measure being calculated. Policies with seemingly similar risk characteristics in the feature space may end up generating significantly different cash flows, diminishing their practical appeal for principle-based calculations. As a solution, this study proposes an algorithm that forms clusters based on Shapley decompositions. The method involves decomposing the overall risk of a contract into clearly separated contributions from each risk driver using a Shapley value-based decomposition. This decomposition allows for a structured and meaningful representation of the policy data, which is then used for selecting the cluster representatives. The proposed method can assist users in explaining the reasoning behind selection of a policy as a cluster representative. Furthermore, the proposed method aligns with the grouping requirements of VM-21: Requirements for Principle-Based Reserves for Variable Annuities, which necessitate representative policies to be selected in a manner that accurately reflects characteristics and criteria with a material impact on the calculated risk measure.

*What factors accelerate adaptation? An analysis of optimal  
investment timing for flood risk adaptation in presence  
of trend, seasonality and stochastic interest rates*

Chi Truong, Macquarie University

Joint work with Michael Goldstein

**23 November, Session B1, Presentation 3**

This paper deals with ‘investment timing’, or how to make decisions on long-term investments to mitigate catastrophic risk where the risk is driven by trends and seasonality, and interest rates vary stochastically over time. Our model combines real options theory, extreme value theory and risk pricing theory to provide a useful decision-support system for catastrophic risk management. Using a case study of flood risk management for New York City, we show that ignoring seasonality, trend or risk aversion can lead to underestimation of the investment values and also unnecessary delay in the project investment. We also show that consideration of stochastic interest rates can provide substantial benefits when investment is optimally timed and accelerate the process of climate change adaptation.

*An augmented variable Dirichlet Process Mixture model  
for the analysis of dependent lifetimes*

Francesco Ungolo, UNSW

**24 November, Session B3, Presentation 3**

Insurance and annuity products issued on multiple lives require the use of statistical models which account for lifetime dependence. This work presents a Dirichlet Process Mixture-based approach which allows to model dependent lifetimes within a group, such as married couples, accounting for individual as well as group-specific covariates. The approach allows to account for right censoring and left truncation as typical of survival analysis. The model is analysed in a fully Bayesian setting and illustrated to jointly model the lifetime of male-female couples in a portfolio of joint and last survivor annuities of a Canadian life insurer. The model shows an improved in-sample and out-of-sample performance compared to traditional approaches assuming independent lifetimes, and offers additional insights on determinants of the dependence between lifetimes and on their impact on joint and last survivor annuity prices.

*Evaluating climate change impacts on mortality,  
life insurance and annuities*

Lintao Wang, University of Melbourne

Joint work with Rui Zhou, Andrew King, Ping Chen

**23 November, Session D3, Presentation 2**

Recent studies provide compelling evidence of the association between non-optimal temperature and excess mortality. With the increasing frequency, duration and intensity of extreme temperature events due to climate change, understanding its effects on human mortality — and the consequent implications for life insurance and annuity pricing and valuation — becomes paramount. This study introduces a comprehensive framework to project human mortality and assess insurance and annuity liabilities under various Shared Socioeconomic Pathways (SSP) scenarios. We refine current environmental epidemiological approaches to establish the relationship between weekly age-specific mortality and daily mean temperature. This refinement includes integrating exposure-to-risk into the distributed lag non-linear model (DLNM), accommodating mixed-frequency sampling, and mitigating overfitting concerns. We also devise a method to consolidate age-specific annual mortality data with weekly mortality data for broader age groups, yielding a detailed age-by-age temperature-mortality relationship. By combining pattern scaling — a prevalent climate science technique — with time series analysis, we incorporate the impact of global warming into the simulated future local temperature paths. These, when paired with temperature-mortality relationships, facilitate the projection of future mortalities under assorted SSP scenarios. Through an analysis of two Spanish regions, we illustrate the shifts in mortality patterns and quantify the differences in insurance/annuity liabilities across various SSP scenarios.

***Investment-consumption optimization with transaction cost  
and learning about return predictability***

**Ning Wang**, Macquarie University

Joint work with Tak Kuen Siu

**24 November, Session D2, Presentation 1**

In this paper, we investigate an investment-consumption optimization problem. The expected return of the risky asset is predictable with an observable and an unobservable factor, and the decision-maker has to learn about the latter one. Both factors are supposed to follow a mean-reverting process. Also, we relax the assumption of perfect liquidity of the risky asset by considering its proportional transaction cost. In such way, a form of friction posing liquidity risk to the investor is examined. Dynamic programming principle coupled with Hamilton–Jacobi–Bellman equation is adopted to solve this stochastic optimal control problem. Applying an asymptotic method with small transaction costs being taken as a perturbation parameter, we determine the frictional value function by solving the first and second corrector equations. In the meantime, Monte Carlo simulation based approximation algorithm is adopted to solve the second corrector equation. Finally, some numerical examples and their economic interpretations are discussed.

***Optimal systematic longevity risk-sharing designs for annuities:  
reconciling policyholder’s and insurer’s perspectives***

**Himasha Warnakulasooriya**, Monash University

Joint work with Brett Inder, Hamza Hanbali, Jackie Li

**23 November, Session B3, Presentation 2**

This paper explores the design of risk-sharing arrangements in flexible annuity products, specifically focusing on systematic longevity risk. The paper derives optimal dynamic risk-sharing rules for the provider and the policyholder. The combination of analytical and numerical results reveals distinct preferred risk-sharing rules between the two parties engaged in the contract. This study’s findings provide insights into the development of optimal risk-sharing mechanisms within flexible annuity products, which is of relevance in pension planning. These insights contribute to the broader understanding of how risk-sharing arrangements can be effectively designed to address longevity risk and benefit all parties involved.

*What is the average surplus before ruin?*

**Jae Kyung Woo**, UNSW

Joint work with E. Cheung, R. Feng, H. Liu

**23 November, Session B2, Presentation 4**

Our goal is to study the moments of the average surplus before ruin in a renewal risk process with a general interclaim time distribution. The average surplus before ruin is calculated as the area under the sample path divided by the ruin time, which provides a new ruin quantity of interest. However, the traditional approach of conditioning on the first claim event is no longer feasible because the ruin time appears in the denominator. To circumvent this, we show that the moments of the average surplus can be obtained by integrating the discounted moments of the area under the sample path with respect to the force of interest. These discounted moments can then be determined using a moment-based discounted density similar to the one in Cheung (2013). We also provide explicit formulas for the case where the claim amounts are a combination of exponentials.

*Why you should not trust explanations in machine learning:  
an example of partial dependence plot*

**Xi Xin**, UNSW

Joint work with Giles Hooker, Fei Huang

**24 November, Session C2, Presentation 2**

The adoption of artificial intelligence (AI) across industries, including insurance, has led to the widespread use of complex black-box models such as gradient-boosting machines and neural networks. Although these models offer enhanced efficiency and accuracy, their lack of transparency has raised concerns among regulators and consumers. To address this, interpretation methods from the growing field of interpretable machine learning have gained attention for understanding relationships between model inputs and outputs. However, while stakeholders may possess a certain level of understanding regarding the limitations of these explanations, there is often a lack of awareness regarding the inherent vulnerability of these methods. Alongside the development of various interpretation methods, a growing body of literature has emerged advocating against the use of these explanatory approaches due to their unreliability and potential for providing misleading information. This study uncovers the vulnerability of permutation-based interpretation methods, with a particular focus on partial dependence (PD) plots. We highlight how these methods are susceptible to adversarial attacks, specifically demonstrating how PD plots can be manipulated by exploiting the extrapolation behavior of correlated features. Our work contributes to the existing literature by developing an adversarial framework that allows developers to manipulate the outputs of PD plots. This framework assumes that auditors can access the black-box model and examine the dataset without making any modifications.

### *The optimal repayment structure of agricultural loans*

**Zheng Xu**, Australian National University

Joint work with Marcos Escobar-Anel, Gaurav Khemka, Timothy Higgins

**23 November, Session B1, Presentation 2**

We investigate the optimal asset allocation and repayment strategy of an agricultural loan under a condition of guaranteed repayment. Using dynamic programming, we solve an expected utility-maximization problem for ‘net’ consumption and terminal wealth. We demonstrate, for a wide family of income structures, that the existence of the loan and the corresponding repayment would not affect the farmer’s optimal asset allocation strategy under a power utility framework because the farmer would invest the outstanding loan amount in a risk-free way to guarantee that the loan would be fully repaid at the end. We use the results of this analytical solution to explore the more interesting question of the impact on farmers’ ‘nominal’ consumption and terminal wealth numerically, noting that the nominal problem does not have a closed-form solution. In the numerical study, we explore various forms of time-based (deterministic) and contingent (stochastic) repayment structures. The results show that the deterministic repayment structures outperform the stochastic ones. Furthermore, the numerical results reveal a convenient structure of the optimal repayment for the nominal problem.

### *Modelling joint life functional disability and mortality*

**Xingying Yu**, UNSW

Joint work with Kyu Park, Jonathan Ziveyi, Michael Sherris, Yang Shen

**24 November, Session D3, Presentation 1**

Our research investigates the dependence between the health states of married couples, along with the variables of age, gender, and time. We develop a 3-state Markov health transition model and estimate four models, incorporating terms to capture the dependence of health states between couples. Our results indicate that models with mortality and disability dependence terms provide a better fit to the data. Spouses’ disability and death have significant impacts on health transitions, and the effects gradually decrease over time. Spouses’ deaths increase mortality rates, while spouses’ disability increase disability rates. The negative impact caused by bereavement effect of spouses’ deaths on mortality rates for males is greater than those for females. Incorporating the frailty term has further augmented the goodness of fit of the model. Our model has practical implications for joint long-term care insurance pricing.

*Time trends in losses from major tornadoes  
in the United States*

**Colin Zhang**, Macquarie University

Joint work with Stefan Truck, Chi Truong, David Pitt

**23 November, Session A1, Presentation 4**

Damage from tornadoes imposes substantial costs on society. This study provides an analysis of time trends in the severity of losses from tornadoes in the United States for the period 1954-2018. Based on information provided by the Storm Prediction Centre (SPC) of the U.S. National Weather Service, we create a dataset of normalized losses from tornadoes spanning 65 years. We then analyze patterns and trends in the total annual losses from tornadoes as well as distributional properties of the damage from individual tornadoes. Our approach allows us to combine observations from the period 1954-1996, when losses from tornadoes were typically reported in a range (e.g. \$500,000-\$5,000,000) with observations from 1997 onwards when an actual estimate of the damage for an event is provided. Our findings suggest an overall national significant decline in normalized losses from tornado events. At the country level, both the severity of damage from individual events and the total annual losses from tornadoes are seen to have reduced over time. We also find spatial variations in time trends for the damage from tornadoes: while for most U.S. states the declining trend in severity is confirmed, an increasing trend of total annual losses from tornadoes is observed for Alabama.