

### **The global pension crisis – A view from academia**

**Mary Hardy, University of Waterloo**

The global pension crisis has been fuelled by aging populations, persistent low interest rates, declining workplace pensions, declining job security, financial instability of social security systems, and systematic underfunding of employer sponsored pension plans. The pension crisis impacts all three of the traditional pillars of retirement income – government benefits, workplace benefits and personal savings.

In this talk we will review the role of academic research in addressing aspects of the pension crisis involving employer sponsored superannuation schemes and drawdown strategies for optimizing individual welfare for DC funds and individual savings.

### **Pricing and hedging variable annuities products: Guaranteed Lifelong Withdrawal Benefits**

**Yue Kuen Kwok, Hong Kong University of Science and Technology**

Variable annuities are long-term unit-linked insurance products that offer various types of guarantees. The variable annuities with Guaranteed Lifelong Withdrawal Benefit (GLWB) were introduced with the unique features that combine the longevity protection of an income benefit and periodic withdrawal benefits. In a typical contractual design of GLWB, the policyholder first accumulates assets during the accumulation phase and later receives annuities payments during the income phase. Since the embedded guarantees may be too costly to the issuers and they are difficult to be hedged, many insurers of variable annuities faced record levels of breakage of their risk hedging strategies. The types of risks faced by insurers in the actual implementation of hedging strategies include policyholder behavior, basis risk and execution risk from poor liquidity of hedging instruments. In this talk, we present the construction of pricing models that examine the impact on the variable annuities values under various withdrawal behaviors of the policyholders. Also, we consider the risk management and hedging of variable annuities with GLWB.

### **Introduction to the Actuarial Research Centre**

**Johnny Li, Actuarial Research Centre, Institute and Faculty of Actuaries**

In this presentation, the speaker will introduce the Actuarial Research Centre (ARC) of the Institute and Faculty of Actuaries. An overview of the ARC's current and ongoing research programmes will be presented. The speaker will also discuss how academics across the world may get involved in the ARC.

### **Undesirable psychological influences on human responses to risk and investment decision making**

**Peter Ayton, City, University of London**

I will present a set of empirical studies that show evidence of deleterious psychological influences on human attempts to judgementally navigate risks. These studies indicate that judgemental management of risk is a hazardous activity in itself and raises questions about the competence and validity of professional decisions under risk. While a well-established program of behavioural finance research has shown psychological biases in individual investors, its extension into institutional investors is under-explored. A series of experimental studies investigating pension trustees' investment decision making shows evidence that trustees' decisions are unduly influenced by irrelevant information. These studies show effects incompatible with the strictly rational perspective on human decisions assumed by classical economic theory.

**Loss reserving prediction error with special reference to the Tweedie family****Greg Taylor, University of New South Wales**

The Tweedie family of distributions is well known within loss reserving. A sub-family is examined in which the mean-variance ratio is constant over cells of a claim triangle. Empirical evidence in favour of this sub-family is presented. Parameter estimation for this family presents some interesting challenges.

Loss reserving prediction error is also discussed, with special emphasis on its components. All of these components are found to have a specific simple property when the claim observations are drawn from the above Tweedie sub-family.

The model error component of prediction error is one on which the literature has comparatively little to offer, but it is considered here in some detail.

**Longevity risk: Retirement product innovation and risk management strategies****Doreen Kabuche, University of New South Wales**

This research develops a new retirement income product which provides partial guarantees as part of retirement benefits in a group-self annuity. Guarantees are common in participating life annuities where are offered through participation in the insurer's profit. The design of this product involves a mix of features of a Group-self annuity (GSA) and a Participating Life Annuity (PLA). Since the need for guaranteed income is becoming an increasingly important issue for retirees, insurance companies and governments, "new" innovative designs for risk pooling products such as GSAs with alternatives typically minimum and/or partial guarantees that are less risky to both insurers and policyholders will provide optimal solutions to longevity risk. The proposed product divides pension savings between two accounts namely, a GSA account and a surplus account. The GSA account provides lifelong retirement benefits while the surplus account is used to adjust such benefits over time. Our new retirement income product aims at providing a financially secure retirement income while offering retirees with the flexibility to switch from a lifelong account to a surplus (capital) account. Australia population- mortality data from the Human Mortality Database and Australia interest rate data are used in setting the product. Smoothing techniques are implemented for both the GSA and surplus accounts to maintain the desired account ratios subject to Australian regulatory requirements.

**Financial engineering: A new longevity bond to manage individual longevity risk****Yuxin Zhou, University of New South Wales**

This research aims to design a new type of longevity bond as a post-retirement investment product for individuals to hedge the idiosyncratic longevity risk. The payoffs of the bond will be composed of monthly coupon payments until death and a principal payment at the time of death. Moreover, this paper also calibrates arbitrage-free Nelson-Siegel (AFNS) interest rate and mortality models with Australian data to calculate the fair price of the bond. Furthermore, this paper constructs a hedging portfolio with existing bonds on the Australian market to minimize the interest rate risk. Finally, the capital requirement for the remaining risk in the portfolio is also calculated in this paper, and the capital cost will be included in the bond price.

**An experimental study of the demand for bundled longevity and health insurance products****Katja Hanewald, University of New South Wales**

We conduct an online experimental survey to elicit and analyse preferences for bundled longevity and health insurance products in China. Participants are asked to advise the allocation of retirement savings across a portfolio of life annuities, critical illness insurance, long-term care insurance, and a savings account for vignette households which differ by wealth and health. Participants also report reasons for allocation choices, exposure to health risks, and retirement planning experience and we collect a comprehensive array of covariates including preferences, financial competence and demographic, and socio-economic factors. The study provides empirical evidence of the interaction between longevity and health insurance products, the impact of having access to hybrid annuity/critical illness/long-term care insurance products on the demand for longevity insurance, as well as insights about the preferences for product attributes. Overall, this research will inform the development of retirement products in China and other developing economies facing population ageing and incomplete insurance markets.

**Optimal hybrid dividends under transaction costs****Hayden Lau, University of New South Wales**

In this work, the cash surplus (or equity) of a risky business is modeled by a linear Brownian motion. Owners can take cash out of the surplus in the form of dividends, subject to transaction costs. However, if the surplus hits 0 then ruin occurs and the business cannot operate any more. We consider two types of dividend distributions: (i) periodic, regular ones (that is, dividends can be paid only at countable points in time, according to a specific arrival process); and (ii) dividend payments that can be made immediately at any time (that is, the dividend decision time space is continuous and matches that of the surplus process). Both types of dividends attract proportional transaction costs, and the latter type also attracts fixed transaction costs. A dividend strategy that involves both types (periodic and immediate) is qualified as hybrid. We conjecture the form of the optimal strategies that maximise the expected present value of net dividends paid until ruin (or both or either types). These depend on the profitability of the business, and the level of (proportional and fixed) transaction costs. Results are illustrated.

**Singular dividend optimization for a linear diffusion model with time-inconsistent preferences****Jinxia Zhu, University of New South Wales**

With the advancement of behavioral economics, the of exponential discounting for decision making in neoclassical economics has been questioned since it cannot provide a realistic way to explain certain decision-making behavior. The purpose of this paper is to investigate strategic decision making on dividend distribution policies of insurance companies when the management adopts a more realistic way for discounting, namely stochastic quasi-hyperbolic discounting. The use of this more realistic way for discounting is motivated by some recent developments in behavioral economics. A game theoretic approach is adopted to establish economic equilibrium results, namely subgame perfect Markov equilibrium strategies. It is shown that (1) under certain mild technical conditions, the barrier strategy with an optimal barrier, which is widely used in the traditional approach to optimal dividend problems, is a perfect Markov equilibrium strategy, (2) the optimal barrier is lower than the barrier of an optimal strategy obtained from the respective time-consistent optimal dividend problem, and (3) the solution based on the barrier strategy does not exist in some situations.

**An optimal investment and debt ratio problem with dividend payments in the frameworks of complete information and partial information****Yang Feng, University of New South Wales**

This paper investigates an optimization problem with investment, debt ratio and dividend payments control on finite time horizon in the settings of complete information and partial information respectively. In the financial market, the stock price is driven by a factor model, which evolves as a linear Gaussian process and is observable to the public in the complete information context. However, in the partial information context, the factor process is unobservable in the market, only the stock price and the interest rate are known. The objective is to find out the combined optimal strategies such that the total expected discounted utility of dividend payments on finite time horizon is maximized. By using dynamic programming approach and Kalman-Bucy filter (in the partial information framework), the value function (in each setting) is the solution of a second-order nonlinear Hamilton-Jacobi-Bellman equation with three state variables. We derive the semi-analytical expression for the value function and the explicit forms of the associated optimal strategies in each setting. We provide numerical studies on a special case. By comparing the optimality results in the partial information context with that in the complete information context, we discuss the implications of partial information on optimality results.

**When (not) to use abstract dependence structures: theoretical and practical considerations****Benjamin Avanzi, University of New South Wales**

We argue that the actuarial modeller should be wary of using abstract dependence structures (e.g. copulas). Such structures are powerful theoretical tools which are useful in some circumstances, but they present dangers and difficulties both from theoretical and practical points of view.

In this presentation, we explain what we mean by “abstract dependence structures”, explain what the main alternatives are, and substantiate the abovementioned warning with some examples and practical solutions.

**On the double counting problem of Bonus-Malus system****Jae Youn Ahn, Ewha Womans University**

A Bonus-Malus System (BMS) in insurance is a premium adjustment mechanism widely used in a posteriori risk classification to set the premium for the next contract period based on the previous claim history of a policyholder. The important feature of BMS is the simplicity of posteriori risk classification where all policyholders share the same posteriori risk classification process, which makes the communication between the insurer and the policyholder easier. While the posteriori risk classification in current BMS is introduced to take care of heterogeneity within each risk class, it is known to be biased depending on the a priori risk characteristic. Such bias was studied in the literature for a long time, and called the double counting problem, meaning that priori characteristics affects both priori risk classification and the posteriori risk classification. Specifically, since all policyholders in the BMS share the same posteriori risk classification regardless of the a priori risk classification, the policyholders with higher priori risk are penalized once more in the posteriori risk classification. While such problem can be resolved by allowing the policyholder with different priori risk characteristics to have the different posteriori risk classification, such resolution is not preferred because the essence of BMS is simplicity in the posteriori risk classification. Alternatively, this paper explains that the double counting problem can be viewed as inefficiency in the optimization process, and the double counting problem can be removed by achieving the full efficiency in the optimization process. As a result, via full optimization setting in BMS, we show that the double counting problem can be resolved without changing the current form of BMS.

**Discrete time risk models with premiums adjusted according to reported claims****Dhiti Osatakul, The University of Melbourne**

In this talk, we propose a discrete time risk model that the premium for the next time period is adjusted according to the current premium and paid claims. This idea is inspired by the principle called “Bonus-Malus system” which allows the insurers to modify premiums of individual policyholders according to their historical claims records. Two rules for the premium adjustment, which are adjustment by aggregate claims and adjustment by number of claims, are considered. The ruin probabilities are calculated by the recursive formulae and the corresponding Lundberg inequalities are also derived. Lastly, we discuss the impact of initial premiums and the rules for premium adjustment on the ruin probabilities numerically. This is joint work with Xueyuan Wu and Shuanming Li.

**A data analytics paradigm for the construction, selection, and evaluation of mortality models****Andrés Villegas, University of New South Wales**

Humanity has made, and continues to make, significant progress in averting and delaying death, which burdens society with increased longevity costs. This has brought to the fore the critical importance of mortality forecasting for actuaries and demographers. Consequently, numerous mortality models have been proposed, with the most popular and commonly-referenced models belonging to a generalised age-period-cohort framework. These models decompose observed historical mortality rates across the dimensions of age, period, and cohort (or year-of-birth), which can then be extrapolated to forecast future outcomes. Recently, a large number of models have been proposed within this framework, many of which are over-parameterised and produce spurious forecasts, particularly over long horizons and for noisy data sets. In this paper we exploit data analytics techniques to provide a comprehensive framework to construct, select, and evaluate discrete-time age-period-cohort mortality models. To devise this robust framework, we leverage two key statistical learning tools -- cross validation and regularisation -- to draw as much insight as possible from limited data sets. We first propose a cross validation framework for model selection, which can be tailored to determine the features of mortality models that are desired for different actuarial applications, including period and cohort-based forecasting. This enables the answering of questions regarding the effects of population size and structure, age, and forecasting basis and horizon on the preferred model selection. We also present a regularisation approach to construct bespoke mortality models by automatically selecting the most appropriate parametric forms to best describe and forecast particular data sets, using a trade-off between complexity and parsimony. We illustrate this using empirical data from the Human Mortality Database and simulated data sets.

**On generalised age period cohort models****Timothy Gummer, Curtin University**

It would be naive to assume that mortality rates are stationary with respect to the passing of time, indeed mortality improvement (more generally the period and cohort effect) is a well-known phenomenon in mortality modelling. In this paper, we analyse this in the male and female populations of Australia, France, United Kingdom and United States of America using data from the Human Mortality Database. We fit age-period-cohort models from the literature: the Lee-Carter model and two cohort based extensions in the Renshaw-Habberman model and the Plat model. We implement so-called back-testing methods to evaluate the 30 years forward forecasting performance of each model on each population. Our results suggest that the Plat and Lee-Carter models both perform well for all the populations investigated with some disparity for some. By contrast, the Renshaw-Habberman model suffered from convergence issues and performed the worst out of the three models. This indicates that the more complex cohort-structure of the Plat model may be required to counteract the loss of parsimony introduced by accounting for the cohort effect.

**Volterra mortality models****Ling Wang, The Chinese University of Hong Kong**

While empirical study supports the existence of long memory feature within mortality data, the impact of the long memory on mortality securities is largely unknown due to the lack of appropriate tractable model for valuation and risk management purpose. In this research, we propose a class of continuous-time Volterra mortality models to incorporating long memory into the valuation of mortality and longevity securities. Although the Volterra process is non-Markovian and non-semimartingale in general, our proposed model has an affine structure that enables us to compute the survival probability in a closed-form solution by taking into account of the historical health records. The flexibility and tractability of the model make it useful in valuing mortality-related products such as life insurance contracts, retirement benefits and many others. Numerical studies are conducted to examine the impact of long memory on various insurance products.

**Optimal liability for time-consistent mean-variance asset-liability management portfolio selection problem****Jiannan Zhang, The University of Melbourne**

In this study, we consider a time-consistent mean-variance asset-liability management portfolio selection problem in which the liability is controllable. The objective is to find an optimal investment strategy and an optimal debt ratio in the financial market consisting of one risk-free asset and one risky asset. By using the forward backward stochastic differential equations (FBSDEs), we derive a sufficient condition and a necessary condition for the open-loop equilibrium strategies. The uniqueness of the strategies is provided. Furthermore, to illustrate our results, we provide numerical examples to show how the parameters impact on the equilibrium strategies and the corresponding efficient frontier.

**Analytic valuation of GMDB options with utility based asset allocation****Eric Ulm, Victoria University of Wellington**

A number of analytic solutions have been found for Variable Annuity Guaranteed Minimum Death Benefit (GMDB) option values under a variety of mortality laws. To date, the solutions are for Risk-Neutral valuation only. Where policyholder decisions are allowed, it is assumed that they act to maximize the risk-neutral value of the GMDB. We examine situations where the asset allocation decisions are made to maximize expected utility rather than option value. We find analytic solutions for both return of premium and ratchet options for small values of bequest motive for a number of mortality laws.

**Asset allocation, consumption, and life insurance purchase with stochastic income in a self-contagious market****Guo Liu, The University of Melbourne**

In this talk, we consider the optimal asset allocation, consumption, and life insurance purchase strategies for a wage earner with a fixed retirement date under a market with mutual-exciting Hawkes jump processes. The Hawkes process captures the impact of contagion that each price jump will influence the probability of the next price jump. The wage earner receives an exogenous stochastic income stream continuously throughout the life. In addition, a lump-sum payment will be paid as a heritage if the wage earner dies before the retirement date. Explicit solutions of the optimal controls are obtained in certain cases by using the dynamic programming principle. For more general cases, we apply the Feynman-Kac formula and develop a numerical scheme. Numerical examples are presented to show that the jump intensities have significant influence on the allocation control but negligible influence on the consumption and life insurance purchase policies.

**Understanding count processes through a Markov-modulated non-homogeneous Poisson process framework****Alan Xian, University of New South Wales**

The Markov-modulated Poisson process is utilised for count modelling in a variety of areas such as queueing, reliability, network and insurance claims analysis. In this paper, we extend the Markov-modulated Poisson process framework through the introduction of a flexible frequency perturbation measure. This contribution enables known information of observed event arrivals to be naturally incorporated in a tractable manner, while the hidden Markov chain captures the effect of unobservable drivers of the data. In addition to increases in accuracy and interpretability, this method supplements analysis of the latent factors. Further, this procedure naturally incorporates data features such as over-dispersion and autocorrelation. Additional insights can be generated to assist analysis, including a procedure for iterative model improvement. Implementation difficulties are also addressed with a focus on dealing with large data sets, where latent models are especially advantageous due the large number of observations facilitating identification of hidden factors. Namely, computational issues such as numerical underflow and high processing cost arise in this context and in this paper, we produce procedures to overcome these problems. This modelling framework is demonstrated using a large insurance data set to illustrate theoretical, practical and computational contributions and an empirical comparison to other count models highlight the advantages of the proposed approach.

**The Central Limit Theorem can fail severely for pairwise independent random variables with arbitrary margins****Guillaume Boglioni Beaulieu, University of New South Wales**

The central limit theorem (CLT) is one of the most fundamental results in statistics, and often met in actuarial applications. For instance, within the Individual Risk Model, the distribution of aggregated claims is frequently approximated by a Normal, and this is done via the CLT. In its most classical form, the theorem states that the standardised mean of independent and identically distributed random variables with finite first and second moments converges in distribution to a Normal. While most actuaries would be familiar with the theorem, the precise meaning of the independence assumption may be unclear to some. How important is this assumption? For instance, does using the theorem on a sample that is only pairwise independent lead to large errors, say in calculating an aggregate risk measure? While it is known that pairwise independence is not sufficient for the theorem to hold (see e.g. Janson, 1988), in this paper we give an explicit example of this fact. We present a sequence of identically distributed, pairwise independent continuous random variables with arbitrary margins for which the CLT fails severely. We find explicitly the limiting distribution of the standardised mean, and find it is positively skewed and with a heavier right tail than the Normal. This calls attention to the dangers of using the CLT when the assumption of mutual independence is not met.



**Optimal control of pension funds under the benchmark approach****Kevin Fergusson, The University of Melbourne**

This paper describes the optimal control of pension funds under the benchmark approach. In particular, we consider Markov control strategies which optimise over the employer's contribution rate into the fund and over the range of possible asset-allocation strategies, while maintaining solvency of the fund. The pension fund model is composed of four assets, cash, equities, bonds and property, as well as a model of benefit outgo that is linked to inflation.

**What is the optimal superannuation guarantee level for Australian retirees?****Yifu Tang, Australian National University**

We address the widespread debate on 'what should be the ideal level of SG for Australian workers'. We use a stochastic dynamic programming model in the life cycle framework to examine the optimal SG level for two types of workers: utility maximizer who makes optimal contribution choices, and worker who makes contributions at the government-specified SG level. We assume that both workers: make optimal choices in the post-retirement phase; are risk-averse with preferences described by a power utility (CRRA) function and are employed full-time throughout their working life. We find significant differences in the optimal SG level for the two types of workers, and at different income levels. For the first type of worker who makes optimal contribution choices, the optimal SG level is 0%, consistent with applying any constraint leading to lower utility. For the second type of worker, there is a positive relation between optimal SG levels and income levels. For example, we find that 10% SG level is optimal for those whose earnings sit at the 30th percentile of the income distribution compared to 13.5% for those on the 70th percentile. From the perspective of government net revenue, a higher SG level is always preferable as the savings on pension payments made exceed the revenue lost on income tax payments earlier in life.

**Influences on employer contributions to defined benefit pension plans in the US****Tanjila Tabassum, Victoria University of Wellington**

Financial insolvency of many private pension funds has put Defined Benefit (DB) pension plans under a microscope over the last few decades. Although government imposes rules to ensure minimum required funding, some sponsors might choose to underfund the plans for short term benefits. This paper investigates the influences- plan and firm specific characteristics, and enforcement of full funding limits- on employer contributions to single-employer defined benefit pension plans in the US private sector for years 1991-2017. We have applied a Heckman test on the sponsor's voluntary contribution (a non-random dependent variable) as we are only observing voluntary contribution of the firms which have decided to contribute more than required. Sponsors are less likely to contribute during economic booms, but contribute more once they have decided to contribute. For plans with a variety of company and plan specific components, a lower pension plan funding ratio than required to achieve the fully funded position increases the likelihood of contribution. The imposition of full funding limitation has a positive marginal effect on the voluntary contribution as opposed to revocation of the limit.

**Impact of shocks on insurance through a financial network****Zhiwei Tong, University of New South Wales**

Financial institutions are interdependent through cross-holdings, which results from the need for diversification but in the meantime creates a channel for the propagation of systemic risk. As a lesson learned from the collapse and near-failure of insurance giant American International Group (AIG) in 2008, it is important to quantitatively understand the systemic risk in insurance. In this work, we consider a network consisting of a number of financial firms, which have opportunities to invest in multiple risky assets. Assume that these risky assets are vulnerable to an exogenous shock, and that external to this network is an insurer who sells a general insurance product to help the firms hedge their losses. Each firm in the network determines how much to purchase of this insurance product to optimize its portfolio according to the mean-variance principle. As a result, the exogenous shock will impact the insurer through the network. To quantify this impact, we examine the insurer's risk reserve. Our main finding is that if the shock size is within a certain range, as the network integration is increased, the impact of the shock is first alleviated and then exacerbated.

**Nested stochastic modeling for risk management****Thi Minh Hang Nguyen, University of New South Wales**

When going through the complex process of calculating capital requirement for a portfolio, companies have to ensure the process is done in a timely manner while maintaining fairly accurate, taking into account company physical resources, risk management policy as well as regulation compliance. This paper aims to couple Least Squared Monte Carlo with clustering in order to improve the accuracy and efficiency of the nested stochastic simulation in the calculation of capital adequacy requirement such as Solvency II and Basel III. In addition, the paper presents the prediction intervals for analysing the accuracy of the model and providing confidence estimates.

**Model risk for pricing guaranteed lifetime withdrawal benefits****Xiao Xu, University of New South Wales**

Variable annuities with guaranteed lifetime withdrawal benefit (GLWB) options have become increasingly popular and dominated for retirement planning. The guarantees provide policyholders the right to withdraw a pre-specified amount from the fund for lifetime regardless of the investment performance. In addition to the downside market risk similar to fixed term GMWBs, insurers are exposed to systematic longevity risk with increasing life expectancy. In this paper, we investigate the pricing of GLWBs when the underlying fund dynamics evolve under various equity modelling assumptions, including the jump diffusion processes, stochastic volatility processes, Levy processes and time-changed Levy processes. We employ the efficient COS and SWIFT methods, which are both Fourier-based numerical techniques by recovering the long-term probability densities to calculate the fair guarantee fees for GMWBs and GLWBs. The significant outperformance of SWIFT method is noted in terms of accuracy and computational time. With the forecast of a multi-factor stochastic mortality model, we evaluate the impact of cohort factors on the pricing of GLWBs. The numerical results are provided to illustrate the sensitivity of fair GLWB charges to various equity and longevity assumptions. Practitioners are advised to consider multiple models to reduce the extrapolation risk in product valuation.

**Long term care financing using home equity release: Evidence from an experimental study****Tin Long Ho, University of New South Wales**

Long-term care (LTC) insurance protects against future unexpected LTC costs. However, due to the costly nature of LTC insurance, take-up rates are relatively low internationally. At the same time, home equity release products, including reverse mortgages and home reversion plans, are also unpopular, as individuals use their housing assets to hedge against future unexpected LTC cost. To solve the difficulties of funding LTC insurance and the substitution effect of housing wealth, we develop a new financial product which allows individuals to use their housing wealth to fund LTC insurance premiums. To ascertain the demand for this new product, we conduct and analyse an experimental online survey that focuses on Chinese homeowners aged 45-64. We make two key contributions to the literature: (1) We suggest viable solutions to both the LTC insurance and the reverse mortgage puzzles; and (2) we analyse the potential demand for different product designs linking LTC insurance and home equity release products. We test how the accessible housing wealth and socioeconomic covariates impact on the demand for LTC insurance. Our results will allow policymakers and businesses to assess the potential demand for the new products and to develop a successful and mature private market for LTC insurance.

**On the Type I multivariate zero-truncated hurdle model with applications in health insurance****Pengcheng Zhang, The University of Melbourne**

In the general insurance modelling literature, there has been a lot of work based on univariate zero-truncated models, but little has been done in the multivariate zero-truncation cases, for instance a line of insurance business with various classes of policies. There are three cases of information missing in the multivariate setting: only records with all zeros are missing, zero counts for one or some classes are missing, or zeros are completely missing for all classes. In this paper, we focus on the first case, so-called Type I zero-truncation, and a new multivariate zero-truncated hurdle model is developed to describe it. The key idea of developing such model is to identify a stochastic representation for the underlying random variables, which enables us to use the EM algorithm to simplify the estimation procedure. This model is used to explain a real health insurance claims dataset that includes claims numbers from different categories with common zero observations not available.

**A stochastic differential game for insurance market with competitive premium****Yang Shen, University of New South Wales**

Insurance premium principle includes the expected loss plus a risk loading factor to cover the loss from adverse claim experience and generate a profit. This paper considers a stochastic differential game with multiple insurers who are competing with each other to sell insurance contracts by controlling their insurance premium. The existing works on this competitive premium problem mainly follow the development of retail pricing models, but fail to consider the randomness of payoffs by selling insurance contracts. The present paper aims to fill in this gap with the large body of literature on insurance surplus process modeling. Specifically, we model the surplus per policy unit by the diffusion approximation to the classical Cramer-Lundberg model. The risk exposure of an insurer (i.e., the number of policies) is assumed to be impacted (linearly) by all insurers in the market. Closed-form Nash equilibrium premium strategies are solved for insurers who are aiming to maximize their expected terminal exponential utilities. To investigate the robustness of equilibrium premium strategies, we further allow insurers to perceive different levels of ambiguity towards the underlying aggregate claim amount process. Closed-form expression for such robust premium strategies are obtained as well, and comparative statics analysis for the model parameters is implemented.

**The rise of peer-to-peer insurance and its mathematical modeling****Runhuan Feng, University of Illinois at Urbana-Champaign**

Peer-to-peer (P2P) insurance is a decentralized network in which participants pool their resources together to compensate those who suffer losses. It is a revival of a centuries-old practice in many ancient societies where members care for each other's financial needs in the event of misfortune. With the aid of internet technology, P2P insurance is becoming a transparent, high-tech and low-cost alternative to traditional insurance and is viewed by many as a huge disruptor to the traditional insurance industry in the same way Uber is to the taxi industry. P2P insurance took an unexpected twist in the Chinese market. A new business model called "mutual aid" is largely driven by many non-insurance tech firms, including the e-commerce giant, Alibaba. In less than three years, the mutual aid industry amassed close to 260 million participants, which is closely 20% of the Chinese population, or equivalently, 10 times the Australian population. Such an unprecedented development is causing huge anxiety for insurers and regulators in China and being closely watched by their peers around the world. Despite the fast-changing landscape in this field, there has no previous academic literature for the theoretical underpinning of the P2P insurance. Our research team at the University of Illinois presents the first such effort to build the mathematical framework for the design, engineering and management of mutual aid and P2P insurance.

**Generic improvements to least square Monte Carlo methods for optimal stopping****Dan Zhu, Monash University**

This paper provides three generic improvements to least square Monte Carlo approaches for solving optimal stopping problems. We emphasise that the methods introduced are both generic and computational efficient in improving the overall lower bounds. The purpose of this note is to introduce and raise awareness of the J Programming Language as a tool for, educational, financial and actuarial computing. J is the modern successor to APL (A Programming Language), a language that developed in the 1960s. APL suffered from its use of an unorthodox character set which did not sit well with ASCII text displays and keyboards.

**A call for actuarial education and research in climate change and sustainability****Giovani Gracianti, The University of Melbourne**

The presentation will describe issues surrounding climate change that will bring up awareness for actuarial education and research. We will discuss this within two big themes: the impact of climate change and global commitment towards a low carbon economy. Actuarial professional bodies and researcher has started to produce research papers as well as tools to increase public awareness of climate change. Some articles also have presented efforts to nurture clean energy. Actuarial science and profession are expected to contribute further to examine climate change and develop sustainability to accelerate growth. This improvement is necessary for the effectiveness of policymakers and industry actions to adopt a sustainable lifestyle. The objective of the presentation is to encourage actuarial students and researcher to be well equipped in understanding and analysing the risks of this current global issue.

**Inculcating students with data analysis techniques within university actuarial subjects****Kevin Fergusson, The University of Melbourne**

The demand for university graduates skilled in data analytics is being driven by employers, industry trends, increased availability of data and advances in technology. These skills are particularly required of graduates of university actuarial programmes, are embodied in the new syllabi of the Australian Institute of Actuaries and other professional actuarial bodies globally. Given the prescribed assessment format of university actuarial subjects, I discuss how students can be inculcated with data analysis techniques based on subject material I have delivered as a university lecturer.

**Curtin University's practice-based approach to teaching Actuarial Science****Mark Hayes, Curtin University**

The global Actuarial Science education is significantly changing, driven by the International Actuarial Association (IAA): [https://www.actuaries.org/IAA/Documents/CMTE\\_EDUC/Documents/2017\\_IAA\\_Education\\_Guidelines.pdf](https://www.actuaries.org/IAA/Documents/CMTE_EDUC/Documents/2017_IAA_Education_Guidelines.pdf)

A key recognition of the new IAA education guidelines is that the education approach needs to be practice aligned with theory. This resonates deeply with Work Integrated Learning (as defined in <http://www.acds-tlcc.edu.au/wil-guide-for-science/wil-basics/>), as the IAA expects students to be more able to understand and solve actuarial problems they would likely be faced with in their professional career.

Both presenters have had successful careers in industry, spanning retirement incomes, life assurance and investments. The aim of the presentation will be to communicate the challenges and successes of integrating practical industry knowledge within the teaching of the Actuarial Science syllabi at Curtin University.

The presentation approach taken will be taking snippets of the Foundation and the Actuary Programs that both presenters teach and explore how they can be taught in two fundamentally different ways:

1. Purely theoretically and technically; or
2. Anchoring the theory using practical examples.

Consequently, the presenters maintain that there is a direct link between the second teaching approach and fostering a deep-learning approach by the student. Both presenters aim to lift the student's grasp of the subject beyond the memorising of the appropriate 'recipe' to apply to a typical example (or surface-learning). A deep-learning approach, in contrast, leads to the ignition of curiosity in the student and a critical appraisal of material.

In short, the presenters incorporate practical experience to help students become better actuaries.

**Coherent mortality modeling for china's provinces in a Bayesian framework****Qian Lu, Renmin University of China, CEPAR UNSW**

China has experienced great improvements in mortality and life expectancy, but there are large variations at the province level. Modelling provincial variations in mortality is important for China. This paper compiles a new comprehensive database containing mortality data for 31 provinces and the national level of China based on online and archive resources and proposes to model the province-level mortality in China in a Bayesian framework. This paper proposes three different hierarchical models in the Bayesian framework with a model based on principal components and random walk process. The 2-level model with a China-province hierarchy allows for information pooling across provinces and reconciliation conditions. The 3-level model with a China-region-province hierarchy pools information across regions and provinces. The 3-level weighted regional model allows for the dependence structure between regions. The models we propose provide good fits and good forecasts. The 3-level weighted regional model performs best with the lowest DIC and provides coherent estimates and reliable forecasts for China and the provinces. The sensitivity analysis shows that based on the data quality of China, the broken trend model has a lower DIC and different trends compared to the random walk process, and researchers should choose the forecast process carefully when modelling the mortality in China.

**Multi-population mortality forecasting using tensor decomposition****Yumo Dong, Australian National University**

We formulate the multi-population mortality forecasting problem based on 3-way (age, year, and country/gender) decompositions. The canonical polyadic decomposition (CPD) and the different forms of the Tucker decomposition are applied.

**The J programming language and financial & actuarial computing  
(notation as a tool of thought -- Kenneth E. Iverson)****William Szuch, Actuaries Institute**

The purpose of this note is to introduce and raise awareness of the J Programming Language as a tool for, educational, financial and actuarial computing. J is the modern successor to APL (A Programming Language), a language that developed in the 1960s. APL suffered from its use of an unorthodox character set which did not sit well with ASCII text displays and keyboards. J is truly a new language by APL's author, Kenneth E. Iverson, and implemented by his son Eric and Roger Hui. J is more than just an ASCII-fied APL but retains the same mathematical principles. The syntax of J is simple: all verbs (functions) have the same priority and parentheses are the only way to alter execution order. J's components are named using English grammar terminology. Function are called verbs, adverbs and conjunctions modify the action of a verb and data is referred to as nouns. (ie. a verb carries out an action on a noun). J is an executable mathematical notation and consists largely of 118 primitives or parts of speech (73 verbs, 11 adverbs, 27 conjunctions, 7 other). We explore through a series of simple examples how one J tacit verb (ie: function)  $v_{wt}$ , the present value factor of \$1 at time T, can be applied to a range of basic compound interest calculations using only the primitives defined in the J.

**Increasing collaboration between educators, researchers and industry****Mike Callan, Actuaries Institute****Georgina Hemmings, Actuaries Institute**

Within the actuarial profession in Australia, there is extensive collaboration between industry, via the Practice Committees, and the Education Council Committee (the body responsible for education standards). Syllabi and materials are defined to ensure that those who reach Fellowship level have a broad understanding of current industry practice. This presentation sets out: the process of industry involvement in the development of teaching materials, including case studies, for actuaries seeking Fellowship status; and ideas on how to involve outputs from actuarial research into the Fellowship educational material and post qualification material. We will seek input from the audience on how to take ideas forward (e.g. re-establish AJAP?).

**Theory informing - practice transforming****Andrew Matthews, Monash University**

The objective is to explore lessons from the transition of Monash University academics from practice to theory that expand our capabilities as actuaries. We explore, themes from the perspective of actuaries entering academia, of academics connecting to business and benefits and challenges of working together. We survey academics and business practitioners to develop key themes: 1. "Back to School" – From practitioners: What does the classroom teach about remembering what's important? 2. "Connecting to Business" - From academics: What possibilities emerge that can heighten student abilities and give new dimensions to where practitioners can benefit from stronger theory? 3. "Interacting" – From joining forces: How do we respond to what our students and stakeholders are telling us? Our challenge. Too often practitioners, academics and students are working on 'it', solving "it", applying "it" but alone don't truly know what "it" is. Success is practice and theory working together to figure "it" out (FIO). At stake is reaching our potential to make a positive contribution for stakeholders – students, researchers, corporate clients, the Actuaries Institute and the public. This session addresses the collision of theory and practice, but with a difference — figuring "it" out together to inform today and transform tomorrow.

**Greed is not good for business: a mind-map****Anthony Asher, University of New South Wales**

The issue of greed is particularly salient in the financial sector in Australia given that the Hayne Commission blamed it for misconduct. The problem is that some see greed as the mainspring of the economy. This paper sketches a mind-map that might be used to bring the insights of different social sciences to bear on these disparate views. Our actions can be traced to psychological drives, desires and satisfactions as well as to the institutional environment. Such an ideal is however subject to temptations, which undermine personal and social virtues and a peaceful and prosperous society. Greed can be seen as chief amongst temptations, both in its addictive power over individuals and its corrosive effects on the fairness of the exchanges that are essential to the operation of social institutions. In addressing greed, we need to be cognizant of our bounded, and often blinded, rationality and the place of institutional narratives and structures that support the virtues rather than magnify the temptations. In particular, markets can be made more just and effective. Change is however ultimately dependent on personal initiative, which may well require the religious conversion of our dopaminergic desires - from greed to love.

**A collaborative approach to building the data analytics principles syllabus****Amanda Aitken, Actuaries Institute****Rob Deutsch, Boxer****Bernard Wong, University of New South Wales**

In 2020, the Actuaries Institute will introduce a new subject into the actuarial education program: Data Analytics Principles (DAP). The subject will be taught by accredited universities as part of the Actuary program. DAP has two primary aims:

1. to extend students' knowledge of modern analytical tools and techniques beyond those introduced in the Foundation Program; and
2. to teach students how to apply this knowledge in real-life business settings, preparing them for more complex and practice specific applications which will be taught in the Fellowship Program.

The syllabus for DAP was developed as a joint initiative between the Actuaries Institute's Data Analytics Practice Committee and representatives from each of the Institute's accredited universities. This presentation will discuss how this collaborative approach was taken, some of the challenges faced and the benefits this approach achieved. A progress update will also be provided on the development of the Data Analytics Applications subject, to be introduced into the Fellowship program over the coming years.