Actuarial Teachers' and Researchers' Conference 2016

The annual Actuarial Teachers' and Researchers' Conference took place on the 4 and 5 July 2016 at the University of East Anglia. This two-day event provided a forum for the exchange of the latest research ideas in actuarial science and related areas.

The overarching theme of "Bridging the gap between academia and industry" aimed to facilitate the discussion between academics and practitioners and to highlight the mutually beneficial inter-dependence between these two worlds.

Selected Abstracts

Aspinall, Nico *We need to talk about sustainability*

Nico Aspinall, Chair of the Institute and Faculty of Actuaries' (IFoA) Resource and Environment (R&E) Board, described some of the actuarial issues in developing models which can assist with the challenges of the 21st century. The R&E Practice area was in part formed to assist with addressing these issues. Nico grouped the issues into a number of areas:

- Limits to growth: warnings of the processes which limit economic growth have existed since Malthus and were re-explored by the club of Rome in the 1970s. While the mechanism and timing of resource limitations causing growth failures remains unclear, the actuarial profession has a bias towards optimism in projecting asset values as the models include long-term return assumptions based on continued expansion of the human system. While it is possible that limits can be raised by technological innovation, actuarial models assume that this will happen, and do not explore what would occur if it does not.

- Extrapolation: without an underlying model to analyse a prediction of the future, the profession tends to use an extrapolative technique. This leads to absurd scenarios if taken to extremes which should highlight concerns with the approach. Given concerns over the limits to growth, we should not be assuming that the average rates of return that prevailed over the 20th century will apply in the 21st.

- Discount rates: the effect of compounding an unrealistic rate of return over long periods of time is to make the distant future virtually valueless under a discounting methodology. In zero return scenarios the distant future is valued on a par with the present.

- Monetisation: the equivalence derived from a consistent value of different assets is misleading as it neglects to take into account the time-ordering of events. Ultimately a valuation system which values all the trees on earth in monetary terms would neglect to note that only trees can create more trees. Valuing natural capital to protect it is a worthwhile pursuit, but not if this provides companies and governments with a choice between maintenance and destruction based on the flawed assumption that money can re-create nature elsewhere.

- Entropy: economics missed the law of entropy due to its formation prior to the completion of thermodynamic theory in the late 19th century. As a result economic maths is based around false

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assumptions of equilibrium, is agnostic to the arrow of time, and has no natural understanding of depreciation (this is added in as a balancing item exogenously).

Nico then went on to describe a number of strengths of the actuarial profession:

- The IFoA is an increasingly visible participant in climate change conferences including at COP21 in Paris. Our policy paper supporting the Paris agreement compared the risk framework for greenhouse gas reductions to the reserving activity insurers take and asked what the acceptable risk of ruin should be.
- The IFoA has been working to introduce the Actuaries Climate Index (ACI) from North America into Europe. The ACI provides a measure of extreme weather such that insurers and other capital market participants could write derivatives or other contracts against it.
- The IFoA in setting up the R&E Board has given itself the ability to research the issues outlined by Nico (Aspinall).

Nico (Aspinall) then outlined two approaches to incorporating the challenges into actuarial science. The first was a shallow approach, making incremental adjustments to our models to account for sustainability issues as we encounter them. The second was a deeper approach, reworking our models to take account of ecological models. The shallow approach was more likely to be taken in the short-term, but the deeper approach more likely to be ultimately successful.

Presentation available at: https://www.uea.ac.uk/documents/1235221/13268694/Nico-Aspinal.pdf/1a6ead6a-6794-4a32-b57d-7d22e00abc31

Chen, Liang *Sampling variation and its impact on the calibration of stochastic mortality models*

This talk considers the impact of sampling variation on the calibration of stochastic mortality models. Random variation in deaths counts results in parameter uncertainty in estimates of age, period and cohort effect in the model. In turn this has an impact on time series parameter estimates.

With small populations, sampling variation causes an upwards bias in the estimated volatility of period effects using standard maximum likelihood methods. We seek to counteract this problem of bias using Bayesian inference.

We use England and Wales (EW) males as a benchmark and then scale this down to simulate small populations. We discuss to what extent Bayesian methods reduce bias in the model volatility, using the full EW population as a benchmark.

Further information at: https://www.actuaries.org.uk/documents/l-chen-atrc-2016

Christiansen Marcus C. *Decomposing life insurance liabilities into risk factors*

The decomposition of (life) insurance liabilities into risk factors associated with various sources of risk such as equity, interest or mortality is of great relevance in view of risk management and product design. Nevertheless, although several decomposition approaches have been proposed, no systematic analysis is available. The presentation shows how to close that gap by introducing properties for meaningful risk decompositions and demonstrating that existing approaches violate at least one of these properties. As an alternative, we propose a novel Martingale Representation Theorem

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decomposition that relies on martingale representation and show that it satisfies all of the properties. We discuss its calculation and present a detailed example illustrating its applicability.

Further information at: https://www.uni-ulm.de/fileadmin/website_uni_ulm/mawi2/dokumente/ preprint-server/2016/2016_-_03.pdf

Cortis, Dominic *Betting Markets: Limitations and Reserving*

Historically, gambling was the inspiration for the initial development of probability. Currently, gambling can be interpreted in many forms including poker, lotto and bingo. Betting on events, such as sports and elections, is an area of gambling that has been of great interest to economists (Peel, 2008) and other researchers mainly because these markets can be interpreted to be a simple alternative to financial markets (Tirole, 1982; Shin, 1993; Sauer, 1998; Lessmann *et al.*, 2009; Cortis *et al.*, 2013). This industry is estimated to make gross gambling revenue of over 40 billion euro per year (H2 Gambling Capital, 2014) and hence its regulation and solvency warrants special attention.

Regulation within the financial sector has been subject to significant amounts of consolidation. A clear example is the Solvency II regime introduced earlier this year to harmonise EU insurance regulation. On the other hand, the regulation of betting operations has been disparate with recent developments focussing on ring-fencing of funds (rather than potential winnings) and countries taking different approaches ranging from very liberal to draconian. Moreover, there is no regulatory regime that sets a formal quantitative requirement on operators. While most bookmakers are asked to have a bank guarantee, the quantity to be reserved is not evaluated using any of the methods apparent in the financial sector.

Excellent literature reviews on the efficiency of betting markets, such as Vaughan Williams (1999), are available but a formal derivation of the key quantitative restrictions has been missing from academic work. Cortis (2015) sets these restrictions by defining the first two moments of the returns on a series of wagers on an event. The key proofs and discussions of the necessary conditions for a market to be operational can be summarised as follows:

- The sum of probabilities implied by odds, for all mutually exclusive outcomes of an event, should add up to more than one as otherwise there would be the existence of arbitrage.
- The probability implied by odds should be greater than the actual probability for each possible outcome in order for a bookmaker to have positive expected profits.
- The expected profitability for a bookmaker (or loss for a bettor) is $\frac{k}{1+k}$ of the total wagers placed, where k is the bookmaker margin/over-round.
- Bookmaker profit is not dependent on knowing the exact probability of an outcome. This is in line with Kuypers (2000) who demonstrated that bookmakers' expected profits increase if they move from efficient to inefficient odds in order to capitalise on bettors' sentimental bias.
- Profitability on multiples/accumulators, that is single bets that are paid out contingent on a series of outcomes, is higher than the profitability on single outcome bets.
- Profitability is guaranteed if the wagers on each outcome are placed in ratio to the implied probabilities.

If the necessary conditions for a bookmaker in setting odds on an event are known, the next step would be to extend them to bookmaker solvency. A novel approach to measuring bookmaker solvency involves subdividing all bets received by a bookmaker in odds ranges in order to calculate overall risk. This model is scalable but still theoretical. Hence it should be subject to more research on how it can be best adapted – by adjusting the number of bundles, using sport as a possible bundle,

the width of each bundle, and the assumptions used. Future work would focus on using real odds, together with simulated bettor profiles, to examine the applicability of the model as well as doing sensitivity tests on the recommended parameters and assumptions.

Further information at: http://ubplj.org/index.php/jpm/article/view/987

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Fitzgerald, Colm *The psychology of Herd-like Behaviour and financial market bubbles*

Colm Fitzgerald, from University College Dublin, presented a summary of the research on risks arising from herd-like behaviour. The research was carried out with Travis Elsum and members of the IFoA Herd-Like Behaviour Working Group. The research had the following aims:

- To investigate the underlying drivers of herd-like behaviour and how it manifests in financial service organisations;
- to raise awareness of herd-like behaviour as a source of risk; and
- to recommend changes to mitigate adverse herd-like behaviour.

An overview of herd-like behaviour was given: defining it, giving examples and using references to published literature. These were used to show that the prudent behaviour of an individual depends on the behaviour of the group to which they belong.

A model to assess and manage the risks arising from herd-like behaviour was put forward based on the distinction between a narrative and an analysis. It was highlighted that narratives typically

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dominate analyses. Therefore, managing herd-like behaviour necessitates managing narratives rather than merely managing analyses. A concept of narrative risk was introduced, being the risks arising from shallow narratives.

Examples were given showing good, bad and "ugly" results from herd-like behaviour with each shown to be dependent on the quality of the overall narrative. A number of potential high-risk areas for herd-like behaviour were discussed, for example, Economic Scenario Generators models, Value at Risk measures, and longevity assumptions. Three case studies were then outlined, taking a deeper look at financial market bubbles, the banking crisis in Ireland and guaranteed annuity options. Bubble risk was defined as the tail risk in any narrative risk.

Macro- and micro-approaches for managing herd-like behaviour risks were discussed. Each was considered to be difficult to implement. For example, using the "Know Yourself Test" is a new approach and involved stepping outside the herd to use it.

An indirect method for managing the herd-like behaviour risks was also put forward. This was based on the reasoning that creative thought, which should reduce the risks from herd-like behaviour, was likely to increase if individuals' self-awareness increased.

Three cultural methods for doing so were put forward in this regard:

- Fostering greater potential for healthy laughter as not being able to laugh at somebody can mean that they have a potentially unhealthy authority, and this curtails self-awareness.
- Introducing regulation to require demonstration of limited amounts of progressive disobedience in regulated firms, to aid making whistleblowing less of an imprudent activity.
- Fostering better levels of curiosity. The ancient Greek word, *Kurios*, meant sovereignty, implying that those who are curious are more in charge of themselves and more self-aware.

Presentation available at: https://www.uea.ac.uk/documents/1235221/13268694/Colm-Fitzgerald. pdf/ad821884-848d-40ec-8459-a07e503ff3d2

Hancock, Ruth on behalf of the CASPeR research team *Long-term care funding: a comparison of England, Wales and Scotland*

This report investigates the financial implications for older people of the differences between the social care funding systems of England, Wales and Scotland. It considers how illustrative older people (vignettes) needing social care would be affected if the funding systems of Wales or Scotland were implemented in England, contrasting that with the effects of the reforms to long-term care (LTC) funding due to be introduced in England in 2020.

Scotland and to a lesser extent Wales have LTC funding systems that are more generous than the system currently in operation in England. However, from 2020 the reforms planned for England will put a cap on an individual's liability to pay towards their care.

The main findings of the analysis presented in this report are:

- Compared with the current English system, a Scottish-style system of "free personal care", the Welsh system, and the reforms due to be implemented in England in 2020 are all more generous.

- The benefits of implementing these systems in England would go to people who are not eligible for state support with their care costs or eligible for support with only part of those costs under the current English system.
- The benefits of a Scottish style free personal care system depend on the level of non means-tested state contribution to care home fees. Under the lower of two levels examined, the lifetime benefits of free personal care might not be any higher than the benefits of the planned English reforms for median earning home-owners.
- The comparisons of the different funding systems depend on the length of time for which individuals need care especially high intensity home care or residential care.
- The Welsh system, which has a maximum weekly charge for home care, can be more beneficial than the English reforms for people who need only home care.
- The English reforms produce benefits on a par with a Scottish-style system of free personal care only for people who need care long enough to benefit from the cap on care costs.

Further information at: http://www.pensionspolicyinstitute.org.uk/uploaded/documents/CASPeR/20160613%20CASPER%20Longterm%20care%20funding%20-%20EngScotWales%20Report.pdf

Jones, A. W. and Zalk, T. *Industry-academic collaboration: exploring nexus shocks*

In 2013 the research report, Resource Constraints: Sharing a Finite Word. Implications of limits to growth for the Actuarial Profession (Jones *et al*., 2013), commissioned by the IFoA and carried out by a group of academics and practitioners was launched. This report, alongside annual literature reviews by the IFoA R&E Group, was intended to support ongoing dialogue between the actuarial profession and the research community. The area of focus, namely trends in global resources and how these trends may impact financial risk, remains a significant challenge although increasing attention has been given to specific aspects of these risks – most notably emerging climate change risks. Country Resource Maps (Global Resource Observatory, 2014) from the Global Resource Observatory, a project which builds on the above research, was presented at the 2014 Actuarial Teachers and Researchers conference.

The theme of the conference was bridging the gap between academia and industry with emphasis on risk models. However, many models still operate on the basis that the recent past is the best possible guide to the future. Given changes in the climate leading to shifting probabilities in extreme weather, geopolitical challenges around the supply of oil and recent global impacts of food productions shocks linked to the Arab Spring, further engagement between academics and practitioners is more important than ever.

Two such partnerships have recently been set up to further this engagement. One, led by Lloyd's of London, explored the risks associated with global food production and led to the publication in 2015 of the Food System Shock report. This explored the plausible direct and indirect risks associated with a global food production shock. Importantly, the focus of this work was on the short term. The second example has just been launched. The new £6 million Economic and Social Research Council Centre for the Understanding of Sustainable Prosperity (CUSP) includes the IFoA as a partner. CUSP explores the transition to new economic paradigms that could potentially solve some of the biggest financial risks that we face today including inequality and environmental degradation. CUSP academics bring a wealth of experience in social, technical and political thinking and aligning this with the experience of actuaries will allow a better and more detailed view of financial risks and opportunities.

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These types of formal partnerships as well as informal collaborations allow us to better build future bridges and specifically we will explore direct potential links to Institute and Faculty working parties such as Climate Change, Financial Inequality and Infrastructure Investments.

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Kulinskaya, Elena and Steel, Nicholas, Gitsels, Lisanne, Wright Nigel and Allen, Sarah *Use of big health and actuarial data for modelling longevity*

This talk touched on statistical problems in Big Data and provided information and the first results from the research project on "Use Of big health and actuarial data for understanding longevity and morbidity risks" funded by IFoA 2016-2020.

Further information at: www.bighealthactuarialdata.ac.uk

Mei, Zhaoxun *Optimal design of structured products*

The project aims to design new products that can be used by insurance companies to smooth investment returns for their customers.

The focus is on new mechanisms for investment risk sharing between customers, and between customers and the insurance company. The project will involve stochastic models for financial markets, stochastic optimisation techniques and application of economic theory to inter-generational risk sharing.

This paper introduces a new product which is inspired by an existing pension product in Denmark examined by Guillen, Jorgenson & Nielsen (2006). Some characteristics of this product are given first. The pricing and hedging of this product is presented in part 2. In the last part, some investigations of this product are discussed. The comparisons between these two products under Expected Utility Theory and Cumulative Prospect Theory (CPT) are given. Investigation of this product under CPT shows the demand for guarantees from customers depends on the length of their investment windows.

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Presentation available at: https://www.actuaries.org.uk/documents/optimal-design-structured-products

Minihane, Anne-Marie *Nutrition, genotype and healthy ageing: choose your parents carefully*

Human life expectancy (HLE) has been increasing at about 2 years per decade for the past 150 years, and between 2010 and 2050 the proportion of older adults (aged more than 65 years) in Europe is projected to rise by 70% (Ezeh *et al.*, 2012). Yet the prevalence of chronic disease in old age remains high. This excess morbidity is socioeconomically patterned and people living in poorer areas of the United Kingdom spend more of their shorter lives with disability – an average total difference of 17 years disability free life expectancy (Marmot, 2010).

Total food intake and diet composition are major contributors to HLE (and health inequalities) with, for example, 50% of cardiovascular diseases prevented by improved diet. The amount and type of dietary fat along with the consumption of fruit and vegetables and other plant-based foods, have emerged as particularly important determinants of HLE and chronic disease risk. However, response to dietary change is highly variable which is likely in large part attributable to genetic differences between individuals.

APOE genotype represents the most widely described common genetic determinant of chronic disease risk and response to dietary change, with *APOE4* carrier status (~25% Caucasians) associated with reduced longevity, and increased risk and earlier age of onset of dementia and cardiovascular diseases (Bertram *et al.*, 2007; Rimbach & Minihane, 2009; Shadyab & LaCroix, 2015). Yet those with an *APOE4* genotype are more responsive to the health benefits associated with positive dietary changes and in particular to dietary fat composition. In the future more widespread use of genetic profiling may provide a tool to identify "at-risk" individuals prior to the appearance of clinical disease. In those identified at being above average risk, regular monitoring and use of bespoke interventions may delay or prevent ill-health. Although the public health and clinical benefits of more widespread genotyping are well recognised there is some concern that miss-use of this predictive (and certainly not diagnostic) genotyping may lead to genetic discrimination (Wauters & Van Hoyweghen, 2016).

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Further information at: https://www.uea.ac.uk/medicine/people/profile/a-minihane#publicationsTab

O'Hagan, Adrian *Actuarial risk matrices: the nearest positive semidefinite matrix problem*

Actuarial risk correlation matrices are often constructed using output from disparate modelling sources and can also be adjusted using subjective judgement, for example, increasing the estimated correlation between two risk sources in order to confer reserving prudence as to potential insurance losses from both sources simultaneously. Hence, while individual elements still obey the necessary assumptions of correlation values, the resultant correlation matrix is often not mathematically valid in the sense that it is not positive semidefinite and hence cannot be inverted. This can prove very problematic in using the matrix in statistical models, for example, in the commonly used multivariate Gaussian density function.

This paper explores methods that allow actuaries to identify the nearest symmetric positive semi-definite matrix to a given initial invalid symmetric correlation matrix. The methods are adapted to adhere to the necessary assumptions underpinning a correlation matrix (namely symmetry and that all elements are between –1 and +1 inclusive). The problem is further finessed by considering the imposition of a block structure on the initial correlation matrix. This commonly employed technique identifies off-diagonal subsets of the correlation matrix where values can or should all be set equal to some constant due to similarity in the nature of the underlying risks and/or with the goal of increasing computational efficiency for processes involving very large matrices.

The problem is initially explored using two mathematical matrix programming approaches: Semidefinite Programming (SDP) and the Alternating Projections Method (APM). Both approaches are adapted to allow implementation of further linear constraints (such as the off-diagonal blocks of fixed values) beyond the classical nearest positive semidefinite matrix problem. "Nearness" is primarily considered in terms of two summary measures for differences between matrices: the Lowest Maximum (Chebychev) Norm and the Frobenius Norm. It is shown that APM is extremely efficient in producing solutions with minimum Frobenius norm but that both SDP and APM fail to converge to matrices with the least maximum norm. However, they can be used to prove the existence of matrices with lower maximum norms than those obtained by default. For this reason, further approaches including the Shrinking Method are explored to provide solutions with the smallest possible maximum norm. Convergence speeds for the various approaches implemented are calculated and compared and sample data and accompanying MATLAB code for implementation of the methods is provided for the reader's convenience.

All methods considered are demonstrated to work well both on artificial correlation matrices and on real actuarial risk matrices provided as part of a collaboration with Tokio Marine Kiln. Ultimately the APM is identified as being superior in terms of the Frobenius norm as it can be demonstrated to work well across the full range of problems considered and is also optimal in terms of convergence speed. The Shrinking Method, building on the output of the APM algorithm, is demonstrated to provide excellent results at low computational cost for minimising the Chebychev norm.

Further information at: http://www.tandfonline.com/doi/full/10.1080/10920277.2017.1317273

Boado-Penas, Carmen *Linking PAYG pensions to life expectancy: a solution to guarantee long-term sustainability?*

The decline in fertility rates, the increase in longevity and the current forecasts for the ageing of the baby-boom generation all point to a substantial increase in the dependency ratio, and this

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will raise serious concerns for the sustainability of Pay-As-You-Go (PAYG) pension systems. Consequently, many European countries have already carried out some parametric reform, or even structural reforms, of their pension systems. Specifically, two-thirds of pension reforms in OECD countries in the last 15 years, OECD (2011), contain measures that will automatically link future pensions to changes in life expectancy, compared with only one country (Denmark) a decade ago.

In the meantime, some other countries have decided to set up Automatic Balancing Mechanisms (ABMs). ABMs can be defined as a set of predetermined measures established by law to be applied immediately as required according to an indicator that reflects the financial health of the system. In this line, Godínez-Olivares et al. (2016) design a new ABM based on optimal strategies of the key variables of the system to restore the sustainability into the system under a non-linear dynamic programming framework.

With this in mind, the aim of this research is to twofold. First, using non-linear optimisation, it seeks to assess whether a sustainability factor linked to life expectancy (or any other demographic factor) is sufficient to guarantee financial stability in the pension system. Second, considering this sustainability factor, it designs different optimal strategies, that involve variables such as the contribution rate, age of retirement and indexation of pensions, to restore the long-term financial equilibrium of the system. These strategies (ABMs) calculate the optimal path of these variables over time and absorb fluctuations in longevity, fertility rates, salary growth or any other kind of uncertainty faced by the pension system.

Our research shows that none of these sustainability factors, related to recent reforms in EU countries, is sufficient to restore the sustainability of the pension systems in the long run unless other measures are applied immediately.

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Further information at: https://doi.org/10.1016/j.insmatheco.2016.05.001

Pittea, Aniketh *Impact of changing population demographics on pension plans*

The generation born in the 20 years following the end of World War II has had a profound impact on long-term economic growth in developed countries over the last half of the 20th century. The retirement of this "boomer" generation has the potential to continue to be a dominant economic factor. In particular, ageing populations will continue to put pressure on the benefit delivery and cost of social security systems in many developed countries. The effect will be compounded if changing population structure reduces asset returns below levels currently anticipated.

In this research, we ask: will the pension plan payments be adequate for the retirement needs of an ageing population?

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We implement existing economic and demographic models in actuarial literature to quantify financial risks underlying large pension plans. This will then enable us to investigate the impact of ageing population on pension plans by incorporating models specifically designed to capture the impact of ageing on both economy and demography.

The interaction between population structure, investments and asset returns will be of interest to pension funds, actuaries and policy-makers, all of whom are interested in the overall health of both public and private pension plans.

Further information at: https://www.actuaries.org.uk/documents/pittea-atrc-2016

Rickayzen Ben *Surveying the long-term care landscape in England following the delay in implementing parts of the Care Act 2014*

LTC has been a topic of political debate in England for many years. The Care Act 2014 was supposed to introduce a cap on the costs of social care which individuals were required to meet, and to introduce a more generous set of means test limits. However, the Government subsequently decided to defer these changes to 2020 for affordability reasons.

In this talk, we consider how this period of delay could be used to reflect upon reforms which would meet the policy intention of protecting people from catastrophic care costs and would facilitate individual understanding of their potential care funding requirements. In particular, we review the options for product development, produce case studies to demonstrate the complexities of the care funding system and review the potential impact on incentives for individuals to save for care costs.

Further information at: https://doi.org/10.1017/S135732171600012X

Smith Andrew D., Jarvis, Stuart and Sharpe, James *Ersatz Model Tests*

This paper describes how statistical methods can be tested on computer-generated data from known models. We explore bias and percentile tests in detail, illustrating these with examples based on insurance claims and financial time series.

Further information at: https://doi.org/10.1017/S1357321717000137