Institute and Faculty of Actuaries

International Mortality and Longevity Symposium

Explaining the past, exploring the future

Aston Business School

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Introduction

Peter Banthorpe
Chair of the International Mortality and Longevity Symposium Committee

Accurately projecting mortality is a complex problem. Complex problems can only be solved by wide ranging collaboration and so it was a great pleasure to welcome a diverse mix of delegates to the International Mortality and Longevity Symposium 2014.

The aims for the Symposium were simple. We aimed to equip delegates with new knowledge and insights that they could effectively apply in their jobs. Many of the delegates were themselves world class experts in projecting mortality and so this was difficult task but, given the varied and excellent line up of speakers, we think we achieved our aim. This Symposium report provides summaries of all the plenary sessions and abstracts for the workshop sessions.

For me there were three preeminent themes running through the symposium: Data, Collaboration and Coherent Forecasting.

Data

The undoubted data "star of the show" was the Human Mortality Database (**www.mortality.org**). Numerous presentations made use of it to validate and compare results derived for one country with many other countries. The enhanced understanding these comparisons bring is enormous.

Of particular note was Professor Hemmingway's lecture describing the Farr Institute's research on large linked medical datasets. It was illuminating to understand the volume of high quality data available at relatively low cost which will radically enhance medical research in the future. The insights generated will no doubt save many lives.

Collaboration

Collaboration with disciplines outside of the actuarial profession was the founding principle of the Mortality Research Steering Committee and we were pleased to see collaboration evident throughout the event. Plenary speakers were drawn from the fields of gerontology, health informatics and demographics and each identified key areas of research where they would like to see more collaboration, both with actuaries and, indeed, other disciplines.

I am sure the relaxed nature of the conference will lead to much future collaboration but of particular interest to me was the feedback from the PhD students who displayed posters in the lounge area. They reported very valuable feedback that will guide and enhance their research demonstrating the value of links between academia and commerce that the IFoA has established.

Coherent forecasting

Whether it be coherence between genders, countries, socio-economic groups or causes of death, the Symposium demonstrated tools and techniques to step beyond projecting a single population group in isolation. Dr Booth's plenary address demonstrated that projection accuracy could be enhanced by referencing the other gender and another country's mortality. Professor Ezzati's address spoke of coherent forecasting by cause of death across territories.

In closing

In closing I was reminded of Sir Harry Burns' excellent pre-conference dinner speech, in which he discussed the determinants of socio-economic variations in health and mortality in Scotland. He extolled the virtues of thinking about salutogenesis (the origin and generation of health) rather than pathogenesis (the mechanisms that create disease). Associated with salutogenesis is the sense of coherence and I was struck how the three elements of a sense of coherence neatly encapsulated what I feel the Symposium achieved by:

- providing insights to enhance comprehension;
- describing new tools and methods for the management of mortality and longevity risk;
- developing a wider sense of the meaningfulness of the work we do.

Plenary sessions

Recent advances in the biology of ageing

Prof Richard Faragher
Professor of Biogerontology, University of Brighton

Professor Faragher provided a highly entertaining start to the symposium covering four points: what ageing is; why it exists in evolutionary terms; how it works and the prospects for effective intervention.

Population ageing is seen as following the Gompertz relationship across most, but not all species. As exceptions, and to demonstrate such a relationship does not seem to be an absolute requirement of all complex organisms, Professor Faragher pointed to some species with very slow or no increase in intrinsic mortality for long periods of time.

Ageing research is about health, not immortality, and Professor Faragher presented the most plausible future outcomes as being compression of morbidity, perhaps associated with an extension in lifespan. Both outcomes would be an improvement on where we currently are. Evidence from model organisms suggest lifespan can be lengthened significantly by selective breeding across many generations, actions which haven't and aren't taking place in humans.

Professor Faragher argued the distinction between ageing processes and age related diseases is a false dichotomy. Supporting this argument Professor Faragher pointed to work on model organisms (*C. Elegans* and mice) where single gene mutants demonstrated greatly extended healthy lives. For humans, examples of Werner's Syndrome and the inverse occurrence of cancer and Alzheimer's disease were cited as further supporting arguments.

The relationship between ageing and age related disease raises the potential for treatments that target ageing pathways that then reduce multiple late life diseases. So what are the mechanisms of ageing? Two broad sets of approaches were discussed: nutrient sensing pathways and tumour suppression mechanisms. In particular, the build-up of senescent cells in ageing bodies was highlighted.

In looking forward to future interventions to delay ageing, three broad categories were identified. Short term opportunities, in the next decade, would centre on the reuse of existing drugs in new ways to treat health problems as a result of fundamental research in gerontology, for example Rapamycin as a potential treatment for mild cognitive impairment. Medium term opportunities could involve drugs currently in development, some as far as Phase 2 trials, e.g. p38 MAP kinase inhibitors, resveralogues or Interleukin 7. Finally in the long-term (30-40 years) drugs may be developed that can target senescent cells.

In closing, Professor Faragher pointed to modelling work which showed that $7 trillion of financial benefit could be realised in the US alone if interventions that "delayed ageing", reducing mortality by 20% by 2050 (with age associated diseases and frailty similarly reduced), could be translated from the laboratory to the clinic. More research funding would be needed to achieve this.

International perspective: theories of longevity

Prof Robert L. Brown
President, International Actuarial Association

Professor Brown referred to the recent history of substantial improvements in longevity in most of the developed world, and discussed three theories of longevity development.

The first was from James W Vaupel: The Advancing Frontier of Survival. Vaupel plots the development of "record life expectancy" (that is the cohort expectation of life at birth in the country that is most advanced in that year), demonstrating that record life expectancy has, in the past, risen in a linear fashion since 1850. Vaupel hypothesises that this maximum longevity will continue to increase at a similar rate. To support the theory, he demonstrates that past projections have regularly underestimated improvements, stating that the best strategy for forecasting future mortality is to linearly extrapolate past trends. Vaupel concludes that the frontier of survival is advancing because senescence (the increase of mortality with age) is being postponed and that this is part of a larger, long-term Life Expectancy Revolution.

Next Professor Brown introduced the theories of Leonard Hayflick: the "four aspects of the finitude of life": ageing, longevity determination, age associated diseases and death. Hayflick suggests that ageing is a stochastic process: age-associated changes appear to be characterised by the loss of molecular fidelity. In other words, ageing is the random, systemic, loss of molecular fidelity that occurs from life's beginning. Repair, maintenance and synthesis processes are capable of maintaining the balance in favour of sustaining molecular fidelity until reproductive maturity. After that, the balance slowly shifts to favour the continued accumulation of un-repaired or un-replaced dysfunctional molecules.
The progressive loss of molecular fidelity increases vulnerability to age-associated diseases. This goes back to work by August Weisman, in 1881, who stated: "Death takes place because a worn-out tissue cannot forever renew itself, and because a capacity for increase by means of cell division is not everlasting but finite."

Finally, Professor Brown introduced the ideas of S Jay Olshansky, "the future course of longevity". Olshansky concludes:

- Gompertz was right – there is a law of mortality.
- Future trends in mortality and longevity will be driven by biology, not past trends. Linear thinking got us in trouble historically, and is still getting us in trouble today.
- A life expectancy of 100 is highly unlikely, but the number of centenarians will rise dramatically.
- Life expectancy is likely to rise rapidly for some, and decline dramatically for others. Education is a longevity trump card.

Olshansky rejects the theories of "continuous linear progression of record life expectancy" stating that although there is no genetic program that limits the duration of life, there are biomechanical constraints on the functioning of body parts that limit how long we live.

Olshansky, highlights the substantial differences between mortality for whites with basic education versus those with college education, and the increasing trend towards obesity. Differences in life expectancy between those of different race and education are widening.

On the positive side, Professor Brown pointed to the philosophy of Craig Venter of Human Longevity Inc., whose goal is "to extend and enhance the healthy, high-performance lifespan and change the face of aging..... For the first time, the power of human genomics, informatics, next generation DNA sequencing technologies, and stem cell advances are being harnessed in one company, Human Longevity Inc., with the leading pioneers in these fields. Our goal is to solve the diseases of aging by changing the way medicine is practiced." Their mission: "It's not just a long life we're striving for, but one which is worth living."

Professor Brown concluded on the positive note that there are two trump cards for longevity: education and financial security. Given that actuaries can contribute to financial security, Brown foresaw an increasingly important role for the worldwide profession in enhancing human life expectancy.

Big health data: perspectives across the patient journey from linking multiple record sources

Prof Harry Hemingway
Professor of Clinical Epidemiology and Director,
Farr Institute London

Professor Hemingway began his talk by emphasising that 'big (health) data' was not just about sheer volume: it involved the linkage of electronic health records (EHRs) collected in heterogeneous formats across multiple databases; which were of variable quality and precision; and incremented in real and lagged time.

The UK is the envy of the world in having the most complete health record with the rich, longitudinal patient records held in primary care linked to national data from disease registries, hospital admissions, mortality, and more recently, genomics. The potential of health informatics to accelerate the pace and scale of health research befits the significant investment by the UK medical research funding bodies in launching the Farr Institute UK in July 2013.

However, gleaning actionable insights from big data is not easy. Professor Hemingway outlined the vision of Farr@London with examples from the research he and his team are engaged in, and the challenges that lay ahead.

Research using EHRs spanned the translational research pathway from discovery through to application; contributing along the pathway to better trial design, better understanding of disease mechanisms, and enabling better treatment and clinical decision-making with more granular phenotypic research.

But to do this at scale, Professor Hemingway identified three key ingredients: data, tools and people.

The team at Farr have begun this process by expanding the range of data that is linked and by curating it to make it 'research-ready' for others to use. New analytical methods are also being developed. In particular, Professor Hemingway is leading the way in developing the research strategy for prognostic research. A key strand in this strategy, and of particular interest to the understanding of longevity risk, is the development of models to predict the risk of a future adverse event or death in individual patients after disease onset.

But the key challenge for health informatics research remains building capacity and attracting an inter-disciplinary cadre of researchers. Professor Hemingway ended his talk with a call for greater engagement with the public (the data providers) to build public trust; and closer collaboration with the users of health intelligence (e.g. industry and the NHS) to deploy this powerful, yet relatively low-cost resource, to do world-class research.

The talk made clear that there was a real shared agenda between the actuarial need for disease-based mortality risk estimates and Farr's prognostic research strategy and the audience was urged to read Professor Hemingway's papers (listed below). Discussion moved on to possible approaches to widening data access, and expanding linkage to include disease-specific data repositories such as for cancer, dementia and diabetes. Big data were not unproblematic - e.g. not very useful for trend analysis - but however messy, Professor Hemingway urged that they must be used now for health and wealth creation in the UK.

Hemingway H., Croft P., Perel P., et al. (2013). Prognosis research strategy (PROGRESS) 1: a framework for researching clinical outcomes. *British Medical Journal,* 346 e5595.

Riley R.D., Hayden J.A., Steyerberg E.W., et al. (2013). Prognosis Research Strategy (PROGRESS) 2: prognostic factor research. *PLoS Medicine,* 10(2).

Steyerberg E.W., Moons K.G., van der Windt D.A., et al. (2013). Prognosis Research Strategy (PROGRESS) 3: prognostic model research. *PLoS Medicine,* 2013;10(2).

Hingorani A.D., Windt D.A., Riley R.D., et al. (2013). Prognosis research strategy (PROGRESS) 4: stratified medicine research. *British Medical Journal*, 346 e5793.

Rapsomaniki E., Timmis A., George J., et al. (2014). Blood pressure and incidence of twelve cardiovascular diseases: lifetime risks, healthy life-years lost, and age-specific associations in 1.25 million people. *Lancet,* 383(9932):1899-911.

How prevention could change future mortality

Prof Majid Ezzati
Chair in Global Environmental Health at Imperial College, London

Professor Ezzati's session addressed the forecasting of mortality rates globally, and the impact of preventative interventions.

He started with a recap of the World Health Organization (WHO) targets for reducing premature mortality from non-communicable diseases (NCDs), which are the current leading cause of death in most regions around the world. Participating countries have agreed to reduce the probability of dying between ages 30 and 70 from four main NCDs (cardiovascular diseases, chronic respiratory diseases, cancer and diabetes) by 25% from 2010 levels by 2025. Target reductions have also been set for underlying risk factors including alcohol use, salt intake, tobacco use, raised blood pressure, obesity and diabetes.

Professor Ezzati estimated the mortality impact of these six risk factor reductions using an epidemiological model accounting for the multi-causality of NCDs and the cumulative long-term impact of varying risk factor exposure.

If the risk factor targets were achieved, he forecasted a 22% (men) / 19% (women) decrease in premature mortality between 2010 and 2025 – most of the way to the WHO's 25% goal. This compared to a reduction of 11% / 10% under the 'business as usual' scenario of current risk factor trends. Achieving the targets would delay or prevent 16 million premature deaths, plus 21 million deaths amongst people over age 70.

The impact would be greatest for low- and middle-income countries – for high-income countries achieving the targets would deliver mortality improvements broadly in line with the 'business as usual' trend. This reduction in global inequality echoed the theme of coherence emerging across the symposium.

Addressing a question from the audience, Professor Ezzati acknowledged that the WHO's target risk factors appeared to focus on cardiovascular disease (rather than, say, cancer). This reflected the emphasis on premature (rather than old age) mortality reduction globally and the prioritisation of factors most open to effective policy intervention. However, he suggested cancer screening as another accessible candidate for policy targets.

Professor Ezzati concluded by sharing some ongoing research on sub-national mortality projections by disease in the UK and US. His forecasts exhibited coherence between males and females, and were consistent with all-cause projections at an aggregate level. He highlighted the relationship between different diseases by local area – with some interesting conclusions. For example, liver cancer appears more closely associated with HIV and homicide than with other cancers (reflecting the influence of alcohol consumption and its socio-economic drivers).

He plans to extend this research to a multi-country environment, using model ensembles to enhance robustness.

Kontis V., Mathers C.D., Rehm J. et al. (2014) Contribution of six risk factors to achieving the 25x25 non-communicable disease mortality reduction target: a modelling study. *The Lancet,* 384 (9941): 427-37.

Coherent forecasting of mortality for multiple populations using functional data models

Dr Heather Booth
Australian Demographic and Social Research Institute, Australian National University

Dr Booth explained that recent decades have witnessed increasing interest and major developments in forecasting mortality. Her talk was in relation to coherent forecasting. She showed a history of past projections of Australian male life expectancy from the 1950s, based on expert judgement, all of which underestimated subsequent improvements. One of the issues, and a problem in its own right, was divergence of the projections of male and female life expectancy. Coherent forecasts disallow divergence between the mortality forecasts of two or more populations. Dr Booth introduced a coherent method of mortality forecasting, the "product-ratio method". This method uses functional principal components modelling, and has been shown to improve accuracy by taking into account relativities among populations. This was demonstrated for sex-coherent forecasting, where the mortality of the other sex is taken into account; and for state-coherent forecasting where the mortality of other populations of the same sex are taken into account. The advantages and flexibility of the product-ratio method were demonstrated.

Dr Booth then asked in relation to any sex-state population whether a sex-coherent or a state-coherent forecast would be more accurate. To address this, she compared forecasts that took the two sexes into account with those that took several countries into account, using data from the Human Mortality Database (HMD) 1950 - 2009 for the component populations of the UK (England and Wales, Scotland and Northern Ireland) by sex. She found that for male mortality, sex-coherent forecasting appeared to be more accurate, whilst for female mortality, state-coherent forecasting was at least as accurate as sex-coherent forecasting. Dr Booth suggested that the apparent importance of taking account of female mortality pointed to the possibility that advantages could be gained from taking account of a lower mortality population. She pointed to the fact that forecast mortality is expected to be lower than observed mortality in justifying this approach. This was put to the test by adopting Japanese mortality as the standard (by sex). Application to some 30 populations by sex, demonstrated that forecast accuracy and bias were improved on average and that their heterogeneities were also reduced.

Dr Booth concluded that forecasting could be improved by adopting the product-ratio method of coherent forecasting with a low mortality standard, but that the discussion on the use of other information to improve forecasting is far from finished, and that further research is necessary, especially on what might be an optimal standard.

In the discussions that followed, Dr Booth was asked how her results might be validated in real life. She responded the method had been tested by using forecasts from the HMD on earlier parts of the period, and then compared with the known developments later on.

Applying insights to mortality projection models

Mr Richard Willets - Partnership
Mr Joseph Lu - Legal and General
Dr Tim Crayford - Just Retirement



Mr Lu opened the session with an overview of the longevity marketplace before focussing on three macro areas of influence for future mortality: Socio-economics, sciences and the health care system.

Socio-economics had been a recurring theme throughout the symposium with focus on whether socio-economic variations in mortality would continue to widen or converge in the future. Mr Lu picked up these themes and discussed how assumptions of convergence in the future would provide higher mortality improvement rate scenarios which could be suitable to parameterise stress tests.

The focus within the sciences was on treatments that delay the ageing process. As Professor Faragher had discussed in the opening plenary, targeting the underlying mechanisms of ageing would effectively treat many illnesses rather than current medicines which generally treat one pathology at a time. Mr Lu provided a scenario test of 80% of UK population of the UK being on such a treatment by 2049.

Finally, for the healthcare system Mr Lu discussed the fiscal and technological challenges facing the healthcare system weighed against the secular changes occurring which may overcome these challenges.

Mr Willets followed with an overview of his experiences applying medical insights to mortality forecasting. Mr Willets advocated the use of conceptual models, either cause of death or disease-based, to capture expert opinion. It was proposed that the preferred approach was to:

- develop models with (5-10) cause-of-death groups;
- allow for changes in disease classification over time;
- parameterise models for each cause group using historic data;
- allow future projections to be modified to reflect expert opinion; and
- blend into aggregate model at high ages.

In obtaining that expert opinion, the need to ask focussed questions related to specific medical conditions, set in the context of recent experience, was discussed. An additional strategy of asking medical experts to comment on particularly controversial public statements that had been made was noted as having been valuable.

Our final speaker, Dr Crayford, drew inspiration from Physics to propose a grand unified theory of mortality. Dr Crayford proposed that the data and modelling techniques now available made this a pursuit that was now more realistic than at any time in the past. As evidence for his proposal he presented the excellent forecasting accuracy of the United Kingdom Prospective Diabetes Study (UKPDS) Outcomes model. By referencing the IMPACT and Archimedes models he provided further evidence of the quality of model that now exists. Finally Dr Crayford proposed a practical solution drawing on a range of models and datasets, triangulated with the CMI projections.

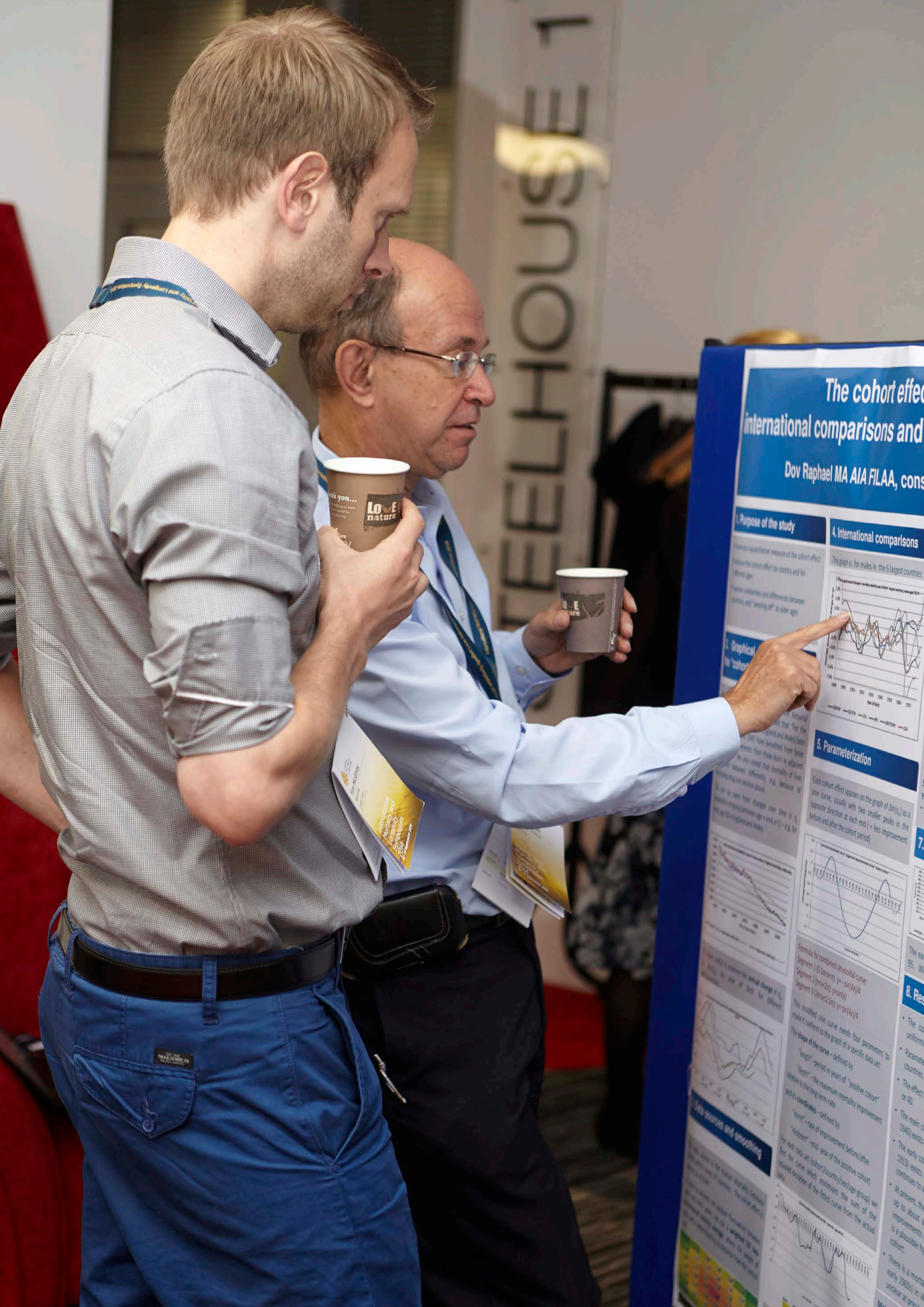
The discussion that followed the presentations was, as expected, passionate. Initial contributions were largely polarised reflecting well-rehearsed arguments around the poor forecasting accuracy of cause of death modelling historically. In response, points were made around the much higher quality of data and modelling techniques available now than previously, as well as the rhetorical argument that all-cause mortality extrapolation techniques require many assumptions themselves, many of which remain implicit.

Essential within cause of death models are the associations between causes of death and disease. It was observed that the strength of these associations cannot be observed directly and have probably been changing over time.

By the end of the discussion it was apparent that many in the room recognised the value of utilising multiple modelling techniques to generate insights before combining them with actuarial judgement.

Discussion over the viable projection time period that a cause of death or disease-based model could be used led to views of between 10-20 years. Fifty year projections were considered to be the realm of science fiction!

The final important comment to be made was that cause of death projections would often rely on a large number of expert medical judgements. Validating these judgements, ensuring they remain consistent with one another and are properly reflected in the modelling is a key challenge for actuaries in the field.


The cohort effec
international comparisons and
Dov Raphael MA AIA FILAA, cons
1. Purpose of the study
4. International comparisons
This graph is for males in the 6 largest countries:
5. Parameterization
Each cohort effect appears on the graph of $\Delta\ln(q_x)$ as a sine curve, usually with two smaller peaks in the opposite direction at each end (= less improvement before and after the cohort period)
Formula for combined sinusoidal curve:
Segment 1 (0.5π<x<2π): y= sin(4x)/4
Segment 2 (2π<x<2π): y=sin(x)
Segment 3 (2π<x<2.5π): y= sin(4x)/4
This modified sine curve needs four parameters to make it conform to the graph of a specific data set.
The shape of the curve – defined by
"length" –period in years of "positive cohort"
"depth" – the maximum mortality improvement relative to the long term rate
and its coordinates – defined by
"curve" – rate of improvement before/after
"midpoint" –mid- year of the positive cohort
For each data set (nation/country/sex/age group) we find the curve which minimizes the sum of the squared deviations of the fitted curve from the actual data.
8. Res
Data sources and smoothing
LOVE nature

Workshop abstracts

Innovations in the CMI's approach to graduation and modelling

Tim Gordon and Jon Palin
Continuous Mortality Investigation (CMI)

The CMI, wholly owned by the Institute and Faculty of Actuaries, is the provider of actuarial mortality tables and projection models in the UK. This session provided an insight into changes to its approach to graduation and model fitting to ensure that its subscribers benefit from tables and models that are both leading and practical. The speakers covered how CMI has updated its approach to graduation, robust mortality projection and features of high age mortality.

Mortality models: comparison and application in old age populations of selected economies

Brian Hu
MetLife

This research examined which of five well-known chosen extrapolative mortality models best captured the trends in old-age population mortality for different age groupings in four different economies. Mortality rates from the Human Mortality Database for the United Kingdom, Poland, Japan and Taiwan were used, encompassing males and females in the 65-89 age group. This allowed assessments to be made across developed and emerging economies, and across Europe and Asia. Comparisons were made across models to understand why some work better for some age groupings in some economies. The research considered the goodness-of-fit of these well-known mortality models to historical population mortality rates, assessed the range of projected future mortality rates, and evaluated the financial impact of mortality uncertainty on annuity prices across the subject populations. Some of the findings which emerged were that the Booth-Maindonald-Smith model tended to work best for most of the selected populations, particularly for female or Asian populations. Perhaps surprisingly, retiring females in the emerging economies can be expected to possibly outlive males in the developed economies selected. In a low yield environment, uncertainty around mortality has a noticeable impact on the range of pricing of annuities. The extent of mortality uncertainty is expected to be less for developed than in emerging economies, and less for females than males.

Developing disease-based models: moving from medical data and research to improved business pricing

Matthew Edwards - Towers Watson
Tim Crayford - Just Retirement

The session started by considering some of the applications of disease-based models, including the pricing of such products as enhanced annuities and healthcare products, the consideration of biologically plausible longevity improvement stresses, and more informed thinking about longevity improvements via input from appropriate medical experts.

The session then considered the three main sources of input in the development of disease-based models: detailed medical datasets, epidemiological research literature, and expert judgement. The speakers gave an overview of some of the more commonly used datasets, including CPRD (Clinical Practice Research Datalink), the Framingham study, and SEER (Surveillance Epidemiological and End Research) and then discussed some of the issues around the other sources.

Next, some of the structural aspects of the models were discussed, including some of the issues involved in deciding on appropriate disease groupings and the related problem of co-morbidities. Examples were provided of typical results derived from the CPRD that might be used to parameterise transitions within a multi-state disease model, for instance the probability of death from different types of cancer, or the probability of diabetes from a healthy starting state.

By way of concrete examples, the session then covered the conditions of atrial fibrillation and breast cancer, looking at some of the conclusions reached on these by careful analysis of the available research literature, and how typical insurance underwriting or rating decisions can be enhanced.

Finally, the speakers demonstrated the PrognoSys disease-based underwriting model developed by Just Retirement, looking at examples based around colorectal cancer survival curves.

PhD Student Workshop: Multi-population mortality models

Vasil Enchev
PhD Student, Heriot Watt University

The speaker investigated a number of new multi population mortality models; derivatives of the famous Li and Lee model. Using the maximum likelihood estimation method, they were able to apply a firm and widely applicable solution, which enabled them to compare the models on a number of points and to order their value. Additionally, a suitable mortality forecasting process was considered for every model.

PhD Student Workshop: effect of size of exposure on parameter estimates and correlations

Liang Chen
PhD Student, Heriot Watt University

There is sampling variation in the death number of a certain population, hence noise to the parameter estimates while modelling. In this study, the speaker investigated the impact of population size on the parameter estimates, hence the projections with bootstrap method. They selected the death number and exposure from England and Wales, male, aged 50-89 last birthday, year 1961-2011 and the model chosen was M7. The group worked out the original estimated death rates with the maximum likelihood estimates of the parameters. By assigning weights to the original exposure, they constructed a series of different sized exposures; assuming their respected death number followed Poisson distribution with parameters equal to the product of original estimated death rates and constructed exposures, with which were then generated 1000 independent scenarios. Finally they calculated parameter estimates for each scenario, projected with random walk and auto-correlation models for period and cohort effect respectively. By comparing the distribution of the parameter estimates of different sized exposure, they found the noise significantly increased by decreasing the exposure size. The same results were obtained for the parameter projection. The speaker compared the distribution of the drift and co-variance matrix of the multivariate random walk model used to project the period effect, and concluded decreasing the size of exposure results in higher variance and lower correlation to the drift as well as upper bias of co-variance matrix from the original one. Investigation to the distribution of the parameters of the AR model with linear drift indicated decreasing the size of exposure leads to significant bias from the original exposure.

Detecting anomalies in national mortality data

Andrew Cairns
Heriot-Watt University

Typically, mortality models are fitted to historical data on the assumption that both deaths and exposures are reasonably accurate. For some countries or subpopulations with a history of good record keeping this might be true. For others, it is not. Late in 2012 the UK Office for National Statistics (ONS) revised its population estimates for the years 2002 to 2010 following the 2011 population census. At some ages the difference between the original and revised estimates was as high as 10% with consequent changes in crude death rates. Professor Cairns discussed how to model and detect errors in the exposures data. Using a forensic approach to error identification he argued that the historical ONS data for England and Wales still contains significant errors that can be quantified now and that concern both middle-aged and very old cohorts.

Global underwriting practices, processes and terminology

Al Klein
Milliman

Work on this project was sponsored by the International Actuarial Association (IAA) Mortality Working Group (MWG). A survey was sent to about 50 countries mid-2012 and 16 countries submitted responses by 2013. The intent was to capture and compare information about the underwriting types, tools, techniques, and terminology used in a broad range of countries. The goals of the study were to:

- provide a centralized source of information on medical and non-medical individual life underwriting practices used around the globe;
- provide a centralized source of the different underwriting terminology used throughout the global underwriting profession to enhance communication between practitioners in different regions and between actuaries and underwriters; and
- enable actuaries to better assess the risk evaluation tools used on a country by country basis as it relates to mortality.

The presentation described the similarities and differences between countries related to:

- types of underwriting;
- underwriting tools;
- market limits;
- regulatory issues;
- potential new approaches to life underwriting;
- impact of underwriting on mortality;
- underwriting as a profession; and
- terminology.

Nature of longevity risk and its behaviours

Sacha Dhamani
Partnership

There have been a number of papers produced discussing how to model longevity risk but it has been a number of years since a paper has been produced considering the fundamental nature of longevity risk. The IAA definitions (Trend, Level, Catastrophe and Volatility) are still the standard definitions used despite many practitioners considering them insufficient as a foundation for modelling longevity risk. Sacha Dhamani discussed a revised conceptual framework for longevity risk and how different types of annuity companies and pension schemes are exposed to longevity risk. The speaker covered trend uncertainty, trend volatility, catastrophe risk, basis risk, underwriting risk, parameter risk and statistical volatility. He also covered how different entities are exposed to the different behaviours.

Creating portfolio-specific mortality tables: a case study and comparison

Stephen Richards
Longevitas

Effective risk management of a portfolio demands accurate and succinct models which explain the main risk factors. Since portfolios have detailed individual records, an ideal approach is to use survival models. Stephen Richards looked at a case study of how the administrator of a large multi-employer pension scheme in Germany created its own mortality tables. In addition to looking at statistical tests of fit, the speaker considered a process for checking the suitability of a model for financial purposes. He also illustrated how a given scheme can test whether its experience is significantly different from other schemes, even after allowing for various known risk factors. The detailed results were published in the European Actuarial Journal in 2013.

Richards, S.J, Kaufhold, K., and Rosenbusch, S. (2013) Creating portfolio-specific mortality tables: a case study, *European Actuarial Journal,* 3(2): 295-319.

Obesity and mortality

Sam Gutterman

On a worldwide basis, the percentage of the population who are obese has grown dramatically over the last several decades, with the prevalence of obesity stabilising recently in the United States. Although numerous studies of the effect of this trend on mortality have been made, due in part to methodological differences and the complexity of the relationship between obesity and mortality, the findings regarding this relationship have been inconsistent and controversial. Sam Gutterman discussed the issues surrounding this relationship and shed some light on the likely effects of this epidemic. In particular, issues associated with the so-called obesity mortality paradox, where mortality experience is lower for those individuals who are overweight and in some cases obese than that for those who are in the normal weight category, was examined in some detail. Although more recently reported studies of the relationship between mortality and obesity seem to indicate a reduced percent of additional mortality of the obese, this may be due in part to the shorter average time that those currently obese have been exposed to their condition, with potentially additional premature deaths that may arise in the future after longer exposure to excess adipose tissue. In contrast, additional health care costs and disability associated with obesity appear significant, especially contributing to the increase in health care costs as the higher percentage of those overweight and obese ages. Although being addressed with many programs and a great deal of publicity, obesity has and will continue to prove very difficult for the individuals and society to manage and overcome.

Modelling mortality by cause of death and socio-economic stratification: an analysis of mortality differentials in England

Andres M Villegas, Madhavi Bajekal and Steven Haberman
University College London, Cass Business School

Background: Affluent socio-economic groups tend to have lower mortality rates and longer lives than deprived socio-economic groups, and, in many cases, affluent subpopulations also experience faster rates of improvement in mortality. The aim of this study was to model mortality trends for leading causes of death and see how they differ between socio-economic groups.

Methods: The group introduced an extension of the Lee-Carter model to allow for the consideration of coding changes in cause-specific mortality data. They then embedded this extension into a multiple population setting to enable the quantification of socio-economic differences in cause-specific mortality. The researchers used mortality data stratified by age, gender, and area deprivation quintiles for the English population aged 25 and older between 1981 and 2007. Seven groups of causes of death were examined: circulatory diseases, neoplasms, respiratory diseases, digestive diseases, mental and behavioural, and other causes.

Results: The analysis revealed a clear association between area deprivation and mortality rates for the leading causes of death, with people living in more deprived areas having significantly higher mortality rates than those living in less deprived areas, and digestive, respiratory and mental and behavioural diseases showing the strongest socio-economic gradient. In addition, for adults aged 25+ and all cause of death groups with the exception of neoplasms, the analysis indicated a widening of the relative mortality gap between more and less deprived areas of England.

Conclusions: Multi-population extensions of the Lee-Carter model offer an approach that can be satisfactorily employed both in the assessment of the magnitude of historical mortality differentials by causes of death and in the projection of the possible future evolution of these differentials. Large mortality inequalities for the main causes of death exist between subgroups of the English population. The persistency and possible widening of inequalities over the past three decades should be considered when designing public policies for tackling inequalities and when managing longevity risk in pension funds and annuity portfolios.

Longevity in the age of austerity

Richard Willets
Partnership

The presentation aimed to answer the following questions. How have trends in longevity changed since the financial crisis? What role has economic austerity played? What does an analysis of global longevity trends and economic growth show? What insights can be derived by examining trends by cause of death?

Adding stochastics to a deterministic forecasting method (such as the CMI method) – calibrated and exemplified with Australian data

Bridget Browne and Xu Shi
Australian National University

Life insurers subject to mortality risk often find it necessary, in addition to having a central projection of future mortality rates, to quantify the potential variation around that central estimate. Most existing methods to achieve this are dependent on the method used to generate the central estimate itself; however, sometimes the central estimates are derived from a deterministic mortality model or from an unknown stochastic model. In this case a variation measure is not directly available from the forecasting model. In this presentation the researchers first modified a simple stochastic model that can be used to attach variation to any best estimate by taking a non-parametric approach. Second, based upon the modelling results, simulation of cash flows for a sample annuity product was presented. Lastly, this model was compared to a recently published stochastic mortality forecast and current regulatory capital requirements in Australia. This method results in very similar prediction intervals to the recent forecast for age-specific mortality rates. The group further found that the current approach to determining regulatory capital requirements may not be meeting the intended objective.

Microsimulation models of disease incidence and development, and of associated mortality

Richard Cumpston
Australian Projections Pty Ltd

Dr Cumpston is a director of Australian Projections Pty Ltd, a company building large household microsimulation models for Australia and NZ. These models use disease incidence, development and mortality assumptions for 123 diseases, based on “Burden of disease and injury” studies by the Australian Institute of Health and Welfare, adjusted to balance with survey and mortality data. Future disease assumptions allow for existing trends and for expert views. The models attempt to replicate the observed mortality differentials for cohabitation status, education and occupation, and their gradual disappearance at older ages. The reasons for these large mortality differentials are not clear, but they may be important to underwriters.

PhD Student Workshop: long and short term survival of total hip replacement cases in UK

Hussein (Muhammad) Wahedally
PhD Student, University of East Anglia

The number of total hip replacement (THR) procedures is increasing worldwide. Using the THIN database of General Practitioners, the group analysed the post-operative hazard of death in the short (≤2 years mortality) and long term for actuarial and medical purposes. The dataset consists of 10,155 THR patients from 429 different GP practices in the United Kingdom. It was found that the post-THR hazard ratio of death of THR cases relative to matched controls is 1.49 and 1.08 in the short and long term respectively. Therefore THR cases die earlier. The hazard of death increases with age of patients at surgery time. The more deprived is the individual's residential area; the higher is the post-THR hazard of death. It is worth to consider introducing new life assurance and annuity products for customers who had THR procedures.

PhD Student Workshop: Gaussian process regression method for forecasting of mortality rates

Ruhao Wu
PhD Student, University of Leicester

Gaussian process regression provides a Bayesian nonparametric approach for smoothing, interpolation as well as extrapolation. The speaker proposed it as an innovative method for forecasting age-specific mortality rates. The speaker first introduced some basic types of Gaussian process regression models to extrapolate mortality data. He further modified the model by adopting spectral mixture kernels and weighted mean function to improve its performance in pattern discovery and trend following. All these models were then applied onto the French total mortality data for testing purposes.
Their predictive results were compared with those obtained from existing models in literature, such as Lee-Carter model and Hyndman-Ullah model.

Towards an industry standard to assess longevity basis risk

Steven Baxter - Hymans Robertson LLP
Andrés Villegas - Cass Business School

Aims: Longevity swaps have been one of the major success stories of pension scheme de-risking in recent years. However, with some few exceptions, all of the transactions to date have been bespoke longevity swaps based upon the mortality experience of a portfolio of named lives. In order for this market to start to meet its true potential, solutions will ultimately be needed that provide protection for all types of members, are cost effective for large and smaller schemes, are tradable, and enable access to the wider capital markets. Index based solutions have the potential to meet this need; however concerns remain with these solutions. In particular, the demographic risk emerging from the potential mismatch between the underlying forces of mortality for the index reference portfolio and the pension fund/annuity book being hedged is the stand out issue that has, to date, prevented many pension schemes and insurers progressing their consideration of index based solutions.

A research team from Cass Business School and Hymans Robertson LLP have been appointed by the joint LLMA/ Institute and Faculty of Actuaries working party on longevity basis risk to produce an applicable framework to assess basis risk.

Methods: The group have critiqued the landscape of published two population models against a range of criteria using a three stage filtering process. Firstly, the mathematical structure of the models was considered in the context of providing credible assessments of basis risk. Secondly models were filtered based upon goodness-of-fit and reasonableness of prediction intervals using synthetic portfolio data. Finally candidate models were assessed for robustness to the data volumes available on the book being hedges. Synthetic portfolio data was generated using a combination of ONS data for England split by deprivation quintile and data on the IMD composition of pension schemes from Club Vita.

Results: It is appropriate to use models calibrated to the experience data of the particular pension fund/annuity book for assessing demographic risk when that book contains more than 25,000 lives and has at least 8 years of historical data.
Two models ("M7-M5" from the CBD family; "CAE+cohorts" from the Lee-Carter family) well suited to assessment of basis risk were identified, along with key factors for choosing between these models.

Conclusions: The group have identified that demographic risk is a key consideration for index-based swaps and highlighted two key candidate models for assessing it. Full details of the resulting assessment framework, including an alternative method for smaller books, are the subject of a presentation to the Institute and Faculty of Actuaries on 8 December 2014.

The managment of long term mortality risk at Swiss Re

Michael Eves
Swiss Re

The session gave the audience an overview of how Swiss Re manages the mortality risks that it (re)insures. The main elements of mortality risk were described including how these are managed in the overall risk landscape of the company's entire risk portfolio. The agenda also included some thoughts on the management actions available to control the amount of mortality risk as well as a look into potential future mortality trends.

The presentation opened with a description of the risk management framework in place at Swiss Re. The acceptance of mortality risk (or any risk) starts by deciding on the company's risk tolerance. This risk tolerance then acts as the basis for risk steering and the setting of limits setting and is defined as the amount of risk that the company is willing to accept within the constraints imposed by its capital and liquidity resources as well as the regulatory environment. In addition it was explained that is also necessary for a reinsurer to maintain capital and liquidity that are sufficiently attractive from a client perspective and to have the capability to be able to continue to operate following an extreme loss event.

It was explained that an extreme loss event is assessed using a 99% tail Variance at Risk measure with a one year time horizon. Within this model life risks can be categorized into one of four categories:

- Shock Risk – e.g. mortality claims caused by a lethal pandemic.
- Trend risk – e.g. deviation in mortality claims resulting from a medical advancement.
- Parameter risk – uncertainty related to pricing or reserving parameters.
- Volatility – non-extreme random fluctuation.

For mortality risks in Swiss Re the shock risk and trend risk are the most important. Presentations of Swiss Re's pandemic model and trend model were then discussed. The focus was on the main underlying factors which drive pandemics, namely the infection rate, number of contacts between individuals, effects of antibiotics, vaccines and antivirals as well as the rates of death per infection of past pandemics. Further discussion focused on the influence of travel on the speed of the spread of a pandemic and on the potential for future pandemics.

For mortality trend risk it was pointed out that there are many models in use. The one used by Swiss Re is effectively an extension to the other models and is described in detail in the paper appearing in ASTIN Bulletin, 2014. There was particular interest in the modelling of long term changes in trend as a comparison with a change in trend that could be seen over a 12 month period.

Controlling the amount of mortality risk can be helped by writing longevity business to provide a hedge against the mortality business. Capital markets can also be used to protect downside risk but are still in a relatively early stage of development. It was explained that improvements in mortality rates are likely to vary by age and other factors so companies need to consider just how correlated are their respective mortality and longevity exposures. A discussion then took place on the capacity provided by the capital markets and their potential for future growth.

Finally there was a quick look at some of the drivers of future mortality trends including an outline of the multi-state model of mortality used by Swiss Re when considering future trends in specific mortality factors.

Boerger, M., Fleischer, D. and Kuksin, N. (2014)
Modeling the mortality trend under modern solvency regimes.
ASTIN Bulletin, 44(1): 1-38.

Cause of Death Working Party update

Donald Macleod, Adrian Pinington, Stephen Courquin

The Cause of Death Working Party is interested in developing a mortality causes-based model to project future mortality. This model would be used to assist in assessing the relative merits of alternate social policy interventions, and for the benefit of actuarial practitioners to assist with the derivation of future mortality bases that may be appropriate to use in the actuarial aspects of longevity work. The issues being investigated in developing the model will have the potential for much wider implications, both at home and abroad, and this provides a great chance for the profession to make a real difference to society.

Poster competition

The IFoA and Symposium Committee encouraged students currently studying actuarial science to attend the Symposium and present a poster outlining their current research to those attending. The posters were displayed in the exhibition area and proved popular with delegates. The students made the most of the opportunity to discuss their research with experienced actuaries from international and UK companies and institutions.

The prize for the best poster was awarded to Jackie Wong, a second year PhD student studying at the University of Southampton.

Jackie Wong receiving his prize from Institute and Faculty of Actuaries President, Nick Salter.

Mortality forecasting with overdispersion

Jackie Wong
University of Southampton

The accurate quantification of uncertainty in mortality forecast is of considerable interest. In this context, Brouhn's Poisson log-bilinear model can describe death counts fairly well. However, it possesses the undesirable property of having the same expectation and variance. Jackie's poster presented several ways to allow for over dispersion.

Determinants of life expectancy of 60+ year olds with a history of myocardial infarction using The Health Improvement Network (THIN) database

Lisanne Gitsels
University of East Anglia

Lisanne identified patient characteristics associated with survival of individuals aged 60+ who have suffered a myocardial infarction. This was done by a multilevel Cox's regression using the UK THIN primary care database. The results are promising for calibration of enhanced annuities.

A parsimonious approach to stochastic mortality modelling with dependent residuals

George Mavros, Andrew J.G. Cairns, Torsten Kleinow, George Streftaris
Heriot-Watt University

The dynamics of standard stochastic mortality models were supplemented with a vector autoregressive residuals processes. The additional model was driven by the detected cohort effect, and introduced short-term dependence between adjacent cohorts in a simple manner. The Bayesian solution imposed the correct degree of parameter uncertainty in the projections.

The cohort effect: an international comparison

Dov Raphael
Consultant Actuary

The poster showed the results of a systematic analysis of the "cohort effect" for over 30 countries represented in the Human Mortality Database. These included graphical presentations using a weighted average of mortality changes, parameterization by fitting a sinusoidal curve to the data, and useful comparisons between countries based on population size and geographical region.

Delegate views

"This is a multi disciplinary symposium with internationally recognised experts among the presenters. The information imparted is at the cutting edge of a number of important fields. Thus, attendance is likely to be rewarded through an advance in the practical and theoretical knowledge of even the most sophisticated students and practitioners."

"A new language is emerging to explain transition form expert knowledge to dependable assumptions for the future."

"A great opportunity to exchange ideas, make contacts and keep abreast of the latest research."

"The conference is informative for people from different fields. Having a background in medical research, it was informative to hear about how actuaries can make use of research results... it was interesting to see how actuaries approach data modelling compared to statisticians."

"New ideas, new thinking, new directions - quality international mix of respected speakers - just what you would hope for from a symposium."

"Thanks very much for IFoA's support on my project. The Mortality Symposium has stimulated to carry out the research for the next stage."

Ruhao Wu,
PhD Student
University of Leicester

"The Mortality Symposium was a really good experience allowing me to have some good discussions with other delegates working in the same area."

Hussein Wahedally,
PhD Student,
University of East Anglia

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