Session 1A – Management of Longevity Risk

Quantification and Management of Longevity Risk in China

Johnny S.-H. Li, Kenneth Q. Zhou, and Wai-Sum Chan

As the annuity market in China develops, the Chinese insurance industry is increasingly exposed to longevity risk. The recently introduced China Risk Oriented Solvency System (C-ROSS) requires both domestic and foreign insurers operating in China have to hold solvency risk capital for the longevity risk they take. In this paper, we study how the longevity risk facing insurers operating in China can be quantified using stochastic mortality models that are developed to suit the demographic situation in China. We also study how different longevity risk management solutions such as securitization may reduce an insurer's C-ROSS solvency capital.

A Value-Based Longevity Index for Hedging Retirement Income Portfolios

Kevin Krahe, Jonathan Ziveyi, Michael Sherris and Andres M Villegas

The availability of a longevity index that closely tracks the value of longevity- linked liabilities has the potential to significantly lower the costs and improve the efficiency of index-based longevity hedging techniques relative to standard mortality rate indices currently referenced in financial markets. This paper presents a universal value-based longevity index constructed from US economic and population data. To construct the index and examine its effectiveness in hedging retirement income portfolios, a multi-population affine term structure model for mortality evolution is adopted, along with a dynamic Nelson-Siegel model for the dynamics of interest rates. We present numerical experiments demonstrating that the proposed hedging framework generates a material reduction in basis risk relative to indices based purely on mortality rates. Beyond longevity risk, the paper notes that interest rate and inflation risks can also materially influence the value of longevity-linked liabilities. Finally, the paper bridges the literature gap between continuous-time and discrete-time multi-population mortality models and notes that the two modelling frameworks suggest relatively comparable hedging outcomes.

Session 1B – Implications to Retirement Planning

Trends in life expectancy and lifespan variation after retirement

Jesús-Adrián Alvarez, Søren Kjærgaard, Malene Kallestrup-Lamb and James W. Vaupel

SUMMARY VERSION SUBMITTED TO THE 2020 LIVING TO 100 SYMPOSIUM

It is well known that life expectancy has increased over time. As a result, individuals spend more time in retirement compromising the stability of national pension systems. Recent reforms of pension systems aim to control this issue by increasing retirement ages so that life expectancy at retirement remains constant over time. However, life expectancy does not describe the complete demographic panorama after retirement. The variation of individual lifespans and its effects in pension systems are still unknown.

In this study we analyze trends in life expectancy and lifespan variation after retirement in Denmark. We compare the current pension scheme against the setting proposed in the Danish pension reform where retirement age is linked to changes in life expectancy. We show that while life expectancy remains constant after the proposed retirement age, higher variation of lifespans persists. This phenomenon might result into detrimental outcomes.

A Study into the Impact of Pre-Programmed Genetic Health Risks in Retirement Planning

N.V.Subramanyan

A brief synopsis of items covered in this paper is given below. The same has been proposed and accepted by the committee set up for the purpose. The narrative is in the same order as far as possible.

1. Human life expectancy and prognosis of health conditions is possible based upon the genetic profile of people which is the actual identity of who one is

2. With the developments in genetic research, it is possible to reasonably identify pre-programmed health risk depending on a persons' DNA. While this is 100 percent possible in the cases of diseases like Huntington's, in some other cases fully developed tests are still in progress though a reasonable estimate is feasible now.

3. It can be reasonably identified how long might a person be expected to live based upon the DNA study through Genetic Scores, Disease Association Analysis, Polygenic Score Analysis and other methodologies. Polygenic disorders, involving multiple parameters and multifactorial influences makes the need of huge data imperative and for their analysis there is need for Big Data and Artificial Intelligence to be used.

4. Impact of family history with respect to health and longevity of relatives on longevity of persons is there and possible to be identified. With proper analysis it is possible to study the effect of relatives' health and heredity on the individuals.

5. There is need to have a framework of regulations to handle the situations arising from these developments. It would be advisable to have well defined regulatory frameworks in place so that all the stakeholders, viz. the customers, Insurance Industry, other institutions like the medical fraternity and overall society stand to benefit. The present situation is that there are three distinct groups of countries based on the stringency of regulations they enforce. A broad convergence of regulatory approach is desirable and may be expected in the future.

Session 2B – Retirement Strategies

AN ACTUARIAL APPROACH TO RETIREMENT STRATEGY METRICS

Mark Shemtob

EXECUTIVE SUMMARY:

Because of the complexity involved in the creation of customized individual retirement income plans, retirees tend to rely on simpler approaches that focus primarily on investment portfolio drawdowns. However, these approaches often suffer from a variety of weaknesses. The primary one being a lack of integration with other potential income sources (and related decisions). These include the age to commence Social Security benefits, whether to purchase a guaranteed income annuity with a portion of the retirement savings (immediate or deferred), the asset allocation risk level, whether and when to use home equity, the order of drawdowns based upon applicable income taxes, as well as others. In addition, some basic drawdown approaches are not well designed to accommodate changing spending patterns as one ages, nor the monitoring of liquidity during retirement, or legacy goals at death. Actuarial methods have the potential to be used to assist retirees in analyzing, testing, and comparing alternative *comprehensive* retirement income strategies incorporating additional sources of potential income and related decisions. In addition, a properly designed application, based on an actuarial method, can also serve an educational purpose even if not used in the final decision process. This paper proposes one such actuarial method for consideration.

REVIEW OF THE DEMOGRAPHY OF RETIREMENT IN THE UNITED STATES

Jacob Siegel

The demography of retirement is important because of the role of retirement in the dynamics of the labor force, its role as a socioeconomic status in our society, and its sizeable impact on local, state, and federal budgets, particularly Social Security expenditures. This paper is intended to review some leading aspects of the demography of retirement not presented together in any earlier publication as well as to bring these materials up to date. I have linked labor force changes, age at retirement, age at entering the labor force, years in retirement, and total years of nonwork lifetime, giving up-to-date estimates of these elements of retirement. In particular, I have spelled out the methodology for developing estimates of median age at retirement by the method of demographic analysis and identified some important next

areas of research, e.g., developing estimates of average age of entry into the labor force by demographic analysis, improving the method of estimating retirement age by allowing for the different levels of mortality of disabled and nondisabled retirees, estimating the relative contribution of mortality, fertility, and immigration to changes in the retired population, applying the demographic estimates given to derive dollars received by SSA beneficiaries.

Session 3A – Aging Measurement and Mortality Modeling 1

Multi-Population Longevity Models: a Spatial Random Field Approach
Nhan Huynh Mike Ludkovsk Howard Zail

We investigate joint modeling of longevity trends using the spatial statistical framework of Gaussian Process regression. Our analysis is motivated by considering the Human Mortality Database that provides raw mortality tables for nearly 40 countries and clearly demonstrates the commonality in global longevity. Yet few stochastic models exist for handling more than two populations at a time. To bridge this gap, we develop a spatial covariance approach that treats mortality data through the lens of smoothing and forecasting noisy input-output relationships. In our framework, multiple populations are approached as distinct levels of a factor covariate, explicitly capturing the cross-population dependence. We demonstrate that our approach not only provides improved accuracy, but intrinsically generates coherent joint future longevity scenarios. It also offers an opportunity to borrow the most recently available data from other datasets, leading to more precise (and statistically more credible) forecasts regarding mortality improvement rates. All the numerical algorithms are implemented using R and Stan statistical languages and are publicly available. We illustrate using numerous figures on multiple European HMD datasets for both Males and Females.

The Application of Affine Processes in Cohort Mortality Risk Models
Zhiping Huang, Michael Sherris, Andrés M Villegas Ramirez, Jonathan Ziveyi

This paper assesses continuous time affine mortality models applied to age-cohort mortality curves. In particular, we introduce the Arbitrage-Free Nelson-Siegel (AFNS) mortality model incorporating level, slope and curvature factors. We estimate and compare models using age-cohort data to capture cohort effects more effectively in the continuous time frame- work. The models explain the variability in cohort mortality curves and allow for Poisson variation in the model estimation using the Kalman filter. The AFNS model facilitates derivation of closed-form survivor curves allowing for efficient valuation of mortality-linked claims. They can incorporate factor dependence into the model structure allowing for age- dependence in the mortality curves. Models based on Gaussian distributed mortality rates, as well as the Cox-Ingersoll-Ross (CIR) process allowing for Gamma distributed mortality rates, are compared including the probability of negative rates in the Gaussian models. The models have appealing features including efficient estimation and computation. They are well suited for theoretical and practical application in finance and insurance.

Session 3B – Mortality Improvement

Does Migration Result in Mortality Improvement:

A Case Study in Taiwan

Chih-Kai Chang Jack C. Yue   Yen-Wen Chen

Mortality reduction has been a common phenomenon at all ages in almost all countries. The trend of mortality improvement usually differs across geographic areas. Generally speaking, mortality rates and mortality improvement in urban areas are lower than those in rural areas, possibly due to the factors such as better living conditions and medical cares. The ignorance of migration effect can cause bias on the long-term mortality projection, resulting in financial insolvency of the commercial and social insurance.

This study mainly aims to measure the impact of rural to urban migration on mortality improvements and their trends in both the rural and urban mortalities, based on the data from Taiwan's public pension system (National Pension Insurance). We also implement the Lee-Carter model to explore the trend of mortality rates from both groups and measure the impact of migration on the mortality improvement. We found that the mortality improvements and their trends of people moving to and from metropolitan areas behave differently, and we cannot ignore the influence of migration.

Session 4A – Mortality Patterns

Demographic perspectives on the rise of longevity

James W. Vaupel   Francisco Villavicencio   Marie-Pier Bergeron-Boucher

This article summarizes the findings of the most significant demographic publications on human longevity and explores possible future trends in life expectancy at birth. Demographic data on age-specific mortality are used to estimate life expectancy, and validated data on exceptional lifespans are used to study the maximum length of life. In the countries doing best each year, life expectancy started to increase around 1840 at a pace of almost 2.5 years per decade. This trend has continued until the present. Contrary to classical evolutionary theories of senescence and contrary to the predictions of many experts, the frontier of survival is advancing to higher ages. Furthermore, individual lifespans are becoming more equal, reducing inequalities, with octogenarians and nonagenarians accounting for most deaths in countries with high life expectancy. If the current pace of progress in life expectancy continues, most children born this millennium will celebrate their 100th birthdays. Considerable uncertainty, however, clouds forecasts of life expectancy and maximum lifespans: life expectancy and maximum lifespan might increase very little if at all or longevity might rise much faster than in the past.

Substantial progress has been made over the past three decades in deepening understanding of how long humans have lived and how long they might live. The social, economic, health, cultural and political consequences of further increases in longevity are so significant that the development of more powerful methods of forecasting is a priority.

Session 4B – Housing, Health, and Social Support of the Elderly

Does living in a retirement village extend life expectancy? The case of Whiteley Village, England

Les Mayhew, Ben Rickayzen and David Smith

The benefits or otherwise of communal living in later life are of considerable interest in the context of a growing and increasingly elderly population because of the continuously rising cost pressures on health and social care and the need to provide more suitable accommodation. Such establishments have the capacity to provide in one location all the needs of residents whilst providing a stimulating and high quality living environment which insulates residents from the day-to-day problems of growing old. Whiteley Village in England, which recently celebrated its 100th anniversary, is one of the main forerunners of this kind of retirement living anywhere in the world. The aim of this study is to investigate the possible benefits of retirement village life with respect to life expectancy i.e. whether Villagers live longer on average than the general population. Our results show that there is strong statistical evidence that female residents, in particular, receive a substantial boost to their longevity when compared to the wider population – at one point in time reaching close to five years. Whiteley's longevity advantage is even greater once we take account of the fact that the resident population is drawn from the poorest pensioners, who would be expected to experience higher mortality rates. Although we were unable to find sufficient statistical evidence that the male residents of Whiteley outlive their counterparts in the wider population, there was certainly evidence that the majority lived at least as long on average (i.e. the effects of living at Whiteley appears to combat the inequalities caused by social deprivation).

Health and Social Care Analysis Regarding the State of Canadian Women Living in the Alone Stage of Retirement

Douglas Andrews and Lori Curtis

Canadians are living substantially longer without increasing years of work; a longer retirement must be resourced within a stable working life. This paper provides results from a larger research` project studying the financial and social implications of providing health care, long-term care, and other support to an aging population. This paper examines the type of health, long-term care, and social

supports older women living alone are likely to require and assesses the adequacy and availability of such support. A companion paper examines the financial requirements. This paper attempts to answer for this group of women such questions as: what mix of health care, long-term care and other supports might this group require; what are the likely gaps in care need and availability; will families and friends be expected to fill any gaps or is government action recommended; can robotics play a role while maintaining dignity?

Although this research focuses on Canada many of its observations have global applications.

Session 5A – Multi-Population Mortality Modeling

Calibrating Mortality Processes with Trend Changes to Multi- Population Data

Matthias Börger, Justin Schoenfeld, Johannes Schupp

The uncertainty in future mortality rates is typically quantified by stochastic mortality models. To this end, the time dependent parameters in these models are projected by stochastic processes. Thus, the choice of these processes and their calibration have a crucial impact on estimates of future uncertainty. Since the commonly applied random walk with drift process has some structural shortcomings (see e.g. Börger et al. (2014)), alternative processes with random changes in the long-term mortality trend have been proposed by several authors. Such trend changes can be observed in the historical data for almost every population. However, data on such trend changes is sparse, and thus, the parameter estimation of these trend processes involves a significant degree of uncertainty.

In this paper, we explain how data on trend changes from several populations can be combined in order to improve the reliability of trend process calibrations for individual populations. We discuss different assumptions on the "similarity" of parameters for different populations and implement those assumptions for the case of the trend change process proposed by Börger and Schupp (2018). In a numerical example we find that the impact on parameter estimates can be substantial. Thus, relying on the sparse data for individual populations only can lead to significant misestimation of future mortality and its uncertainty.

The Mathematical Mechanism of Biological Aging

Boquan Cheng, Bruce Jones, Xiaoming Liu and Jiandong Ren

Despite aging being a universal and ever-present biological phenomenon, describing this aging mechanism in accurate mathematical terms — in particular, how to model the aging pattern and quantify the aging rate — has been an unsolved challenge for centuries. In this paper, we propose a class of Coxian-type Markovian models which can provide a quantitative description of the well-known aging characteristics – the genetically determined, progressive and essentially irreversible process. Our model has a unique structure, including a constant transition rate for the aging process, and a functional form for the relationship between aging and death with a shape parameter to capture

the biologically deteriorating effect due to aging. The force of moving from one state to another in the Markovian process indicates the intrinsic biological aging force. The associated increasing exiting rate captures the external force of stress due to mortality risk on a living organism.

The idea of the paper is developed from Lin and Liu (2007). A big difference is that, in this paper, our model uses a functional form for model parameters, which allows a parsimonious yet flexible representation for various aging patterns. Our proposed mathematical framework can be used to classify the aging pattern and the key parameters of the model can be used to measure and compare how human aging evolves over time and across populations.

Session 5B – Pensions and Longevity Risk

Fully Funded Pensions for Centenarians

Jonathan Barry Forman

At retirement, workers want to have enough income to support themselves throughout their retirement years. In that regard, financial planners often suggest that retiring workers should aim to replace 70 to 80 percent of their annual preretirement earnings. Social Security benefits typically replace around 35 percent of the typical worker's preretirement earnings. That leaves another 35 to 45 percent of preretirement earnings that needs to be financed through pensions and other savings, but most retirees have little in the way of other savings. Accordingly, this Paper focuses quite simply on how pensions alone could and should be designed to replace, say, 40 percent of the typical worker's preretirement earnings throughout their retirement years. In particular, this Paper is concerned with how to fully fund private pensions for centenarians (i.e., retirees who live to be 100 or more).

After some introductory remarks, Part II provides an overview of Social Security, pensions, annuities, and other lifetime income mechanisms, and Part III focuses on funding issues for Social Security and pensions. Part IV then explains pension benefit accrual and pension funding. First, Part IV.A develops a model traditional defined benefit plan that would provide a typical retiree with a pension that would replace 40 percent of her preretirement earnings, and Part IV.A also shows how to fully fund that model plan. Second, Part IV.B then develops a model defined contribution plan that would replace 40 percent of a typical retiree's preretirement earnings and shows how to fully fund that model plan. Part V then brings some real world considerations into the analysis, and Part VI discusses some options for reform, In particular, Part VI considers various options for redesigning—and fully funding—real-world defined contribution and defined benefit plans. Finally, Part VII offers some concluding remarks.

How Amending Old Age Security Would Improve the State of Canadian Women Living in the Alone Stage of Retirement

Lori J. Curtis and Douglas Andrews

Canadians are living substantially longer without increasing years of work; a longer retirement must be resourced within a stable working life. This paper provides results from a larger research project studying the financial and social implications of providing health care, long-term care, and other support to an aging population. In this paper the focus is on the income requirements of older women who are living alone. It presents information regarding amounts available under current programs and draws conclusions regarding the adequacy of such programs. It shows how amending Old Age Security would improve adequacy and estimates the cost of such an amendment.

Session 6A – Aging Measurement and Mortality Modeling II

Rotation of the Age Pattern of Mortality Improvements in European Union Member States

Peter Vékás

Human mortality tends to decline in the long run, which is fortunate for humans, but less so for pension and health insurance schemes and annuity providers. Empirical studies have shown that rates of mortality improvement depend heavily on the age, gender and country in question, and additionally, they also tend to change in time. More specifically, the historical acceleration of mortality decreases among the elderly   and a simultaneous slowdown of improvement at younger ages, which are sometimes jointly referred to as the rotation of the age pattern of mortality decline, have been observed in several populations. After a concise summary of the most relevant literature, this paper suggests a simple, largely data-driven methodology with few assumptions for the empirical examination of the rotation phenomenon in historical mortality datasets. These techniques are then applied on United Nations data from the period between 1950 and 2015 for both genders and all 28 countries of the European Union. The results indicate that rotation has indeed taken place in numerous member states, but its presence is far from universal, and it appears to have been notably more prevalent in populations of women than among men. Life expectancies seem to predict degrees of rotation only in the former Eastern bloc despite prominent literature that suggests otherwise, while increments of life expectancies over the observed period are better predictors of the degrees of rotation in the case of Western European women.

Short- and Long-Term Dynamics of Cause-specific Mortality Rates Using Cointegration Analysis

Séverine Arnold and Viktoriya Glushko

This paper applies cointegration analysis and vector error correction models to model the short- and long-run relationships between cause-specific mortality rates. We work with the data from five developed countries (USA, Japan, France, England and Wales, and Australia) and split the mortality rates into five main causes of death (Infectious & Parasitic, Cancer, Circulatory diseases, Respiratory

diseases, and External causes). We successively adopt the short- and long-term perspective, and analyze how each cause-specific mortality rate impacts and reacts to the shocks received from the rest of the causes. We observe that the cause-specific mortality rates are closely linked to each other, apart from the External causes that show an entirely independent behavior, and hence, could be considered as truly exogenous. We summarize our findings with the aim to help practitioners set more informed assumptions concerning the future development of mortality.

Session 6B – Disease and Longevity

Chronic Diseases and Longevity risk:

An Application to Type II Diabetes Insurance Products

Hsin-Chung Wang   Jack C. Yue

Prolonging life is a global trend and population ageing is speeding up in many countries. As a result, more medical expenditures are used for chronic diseases since the elderly often have chronic diseases. For example, about 3/4 and 1/2 of Taiwan's elderly have at least one and two chronic diseases, respectively. Diabetes is a common chronic disease and many serious health conditions are connected with diabetes. Total estimated cost associated with diabetes in the United States was $245 billion in 2012. However, many people are not aware that diabetes is common and at least 23.8% of patients do not know they have diabetes. (Source: U.S. National Diabetes Statistics 2017) The numbers of deaths related to diabetes are increasing and it becomes the 5th and 4th cause of death in 2017 for the Taiwan men and women, respectively. (Source: Taiwan's Ministry of Health and Welfare)

In this study, we aim to evaluate the cost of diabetes and to design insurance products to deal with the disease, using the data from Taiwan's National Insurance (NHI). In particular, we are interested in the incidence and mortality rates of diabetes, as well as its medical usage. We use mortality models, such as the Lee-Carter and Age-Period-Cohort models, to explore their trends. Also, we will use the continuous prescription for chronic diseases to determine whether people know they have diabetes, since people with the continuous prescription can have 3-month refillable prescription under the NHI. The empirical study is based on two data sets from the NHI, and both data sets are one-million random samples of Taiwan people: one for the group of ages 0-99 and the other for ages 65-99, accounting for about 4.6% and 45.7% of Taiwan's populations in each age groups. The advantage for using the data set of ages 65-99 is to increase the sample size of the elderly and thus increases the stability of analysis results.

We found that the incidence and mortality rates of diabetes change with a constant and stable path, and the Lee-Carter model can provide fairly satisfactory estimates. The analysis results also indicate that the people with diabetes without taking diabetes medication have higher mortality rates, than those taking diabetes medication regularly. We also demonstrate how these results can be used to design insurance products associated with diabetes, which can help the insured and their families to face the consequence. In addition, we discuss different criteria for judging whether people have diabetes in commercial insurance and show that they can be related to the possibility of moral hazard for the diabetes products. The judging criteria of diabetes vary a lot between different doctors.

Understanding Multimorbidities
Sam Gutterman

The prevalence of multimorbidities has and will continue to increase as both the population ages and the number of those who have not died prematurely due to a chronic condition increase. This is indicative of the heterogeneity of the population experiencing an individual condition. The complexity of multimorbidity and the lack of consensus on how to define and measure contribute to the challenges underlying multimorbidity research and treatment lead to many challenges. As its prevalence increases, the impact of multimorbidities on the individuals affected and society as a whole, through outcomes such as mortality, disability, frailty, functional decline, and health care costs, need further assessment. This paper focuses on an understanding of the underlying concepts involved and its implications on mortality and health care.