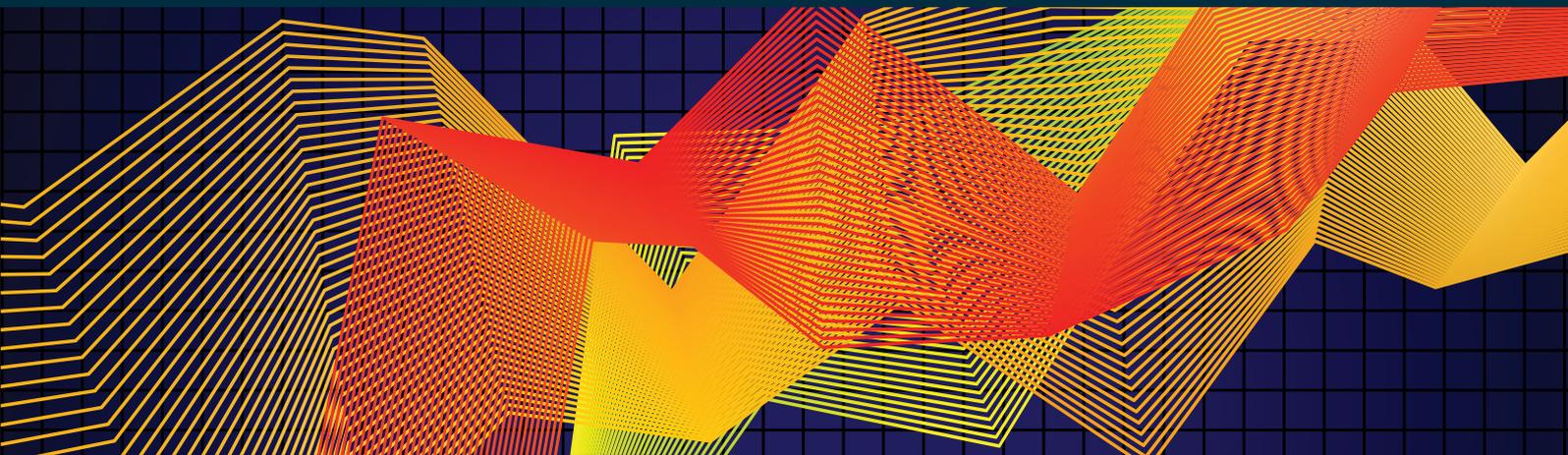


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The AJAP relies upon the goodwill and effort of many people to review papers and notes prior to publication. The Editor is grateful for the help of the reviewers of papers and notes for this Volume.

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FROM THE EDITOR

This volume focuses on two of my loves, mortality research and actuarial education. The first two papers offer a further look at the issue of better forecasting mortality rates and in particular making use of such forecasts to provide tools to better determine the cost of retirement. In the third paper we have a survey of student views of part I, II and III of our actuarial education structure, a very timely piece given the ongoing conversations regarding the future education of actuaries.

Dr Colin O'Hare PhD, FIA, FIAA, FHEA
EDITOR

Modelling defined contribution retirement outcomes: A stochastic approach using Australia as a case study

THOMAS SNEDDON, DR ZILI ZHU AND DR COLIN O'HARE



Thomas Sneddon



Dr Zili Zhu



Dr Colin O'Hare

ABSTRACT

In this paper we present a stochastic forecast model in a defined contribution pension system for projecting the accumulation and decumulation phases from an individual fund perspective. We use the Australian superannuation system as the context to demonstrate this “SUPA” (Simulation of Uncertainty for Pension Analysis) model. The SUPA model can be used to simulate the evolution of superannuation fund balances across time during the accumulation and decumulation phases. The model comprises four elements: (1) a stochastic projection of investment returns; (2) a stochastic projection of income levels (upon which contributions to the fund are based); (3) a projection of levels of withdrawal in retirement; and (4) a stochastic projection of increasing longevity (life table). The combination of these four elements within the SUPA model is described in detail in this paper. One application of the model is demonstrated through a case study involving recent Australian legislative amendments. In this example, we show how the model can be used to forecast likely outcomes (i.e. whether individuals will have sufficient funds in retirement), under the current superannuation structure and a previous structure. This will demonstrate how the SUPA model can be used to model the potential impact of any changes to a superannuation system.

KEYWORDS

simulation, superannuation, mortality

1 INTRODUCTION

The Australian superannuation system obligates employers to pay a contribution of salary (currently 9.5% p.a.) into an employee's nominated superannuation fund. This fund cannot be accessed until retirement and, owing in part to the high participation rate, is globally recognised as a success in assisting citizens to provide for their retirement needs. However, in line with other developed countries, Australia is facing demographic challenges as life expectancy increases and the "baby boomer" generation of the 1940s and 1950s reaches retirement age.

These demographic changes will impact on the ability of the existing superannuation system to play a significant role in funding individuals' retirement. The superannuation system in Australia is around 25 years old and is still relatively immature, although more people with substantial superannuation funds are reaching retirement now. As the scheme reaches maturity there will be many more individuals relying on their superannuation funds to support their retirement lifestyles. As more data on individual superannuation funds becomes available, we can study the current structure and assess if the current superannuation system is adequate for achieving its objectives in this challenging context.

In this paper, we describe the stochastic simulation model: the SUPA (Simulation of Uncertainty for Pension Analysis) model. The model has been developed as part of a research project funded by the CSIRO–Monash Superannuation Research Cluster to assist in evaluating the current Australian retirement income system, and to investigate and assess potential solutions to issues highlighted by the study. The paper outlines some key elements of this stochastic engine and the underlying mathematical models which have been developed in accordance with established actuarial science principles. The paper then provides a case study example to illustrate how fund projections produced by the SUPA engine can be utilised in the assessment of the adequacy of the current superannuation system.

In the next section we review the literature surrounding the modelling of retirement income, to place the proposed model within context. We then discuss the methodology used to develop the SUPA model in section 2, and section 3 discusses a case study performed utilising the model. Section 4 concludes.

2 LITERATURE REVIEW

This work contributes directly to current literature surrounding the adequacy of Australia's retirement income system, but it is also applicable internationally

where defined contribution is becoming the main source of retirement income (Holzmann 2013). We develop a stochastic model to study future fund growth and possible contraction to permit rigorous investigation of pre-retirement contribution and investment strategy in addition to post-retirement withdrawal and investment strategies.

Deterministic modelling of mean superannuation outcomes has been far more common relative to stochastic modelling (see, for example, Rothman 2011; Keegan et al. 2013); however the incorporation of stochastic elements will lead to a more realistic and rich forecast able to illustrate the range of likely outcomes, rather than merely the mean values being predicted. Such a stochastic modelling approach can present more realistically the uncertainty around retirement adequacy, in addition to enabling a more holistic assessment of current and possible alternative superannuation policy settings.

2.1 Simulation-based retirement income research outside Australia

The academic field of simulation-based pension policy research has advanced substantially in the last 40 years, since the development of early microsimulation models, such as the Dynamic Simulation of Income Model (DYNASIM) in the United States in the early 1970s, as rapid escalation in computer processing power has permitted the creation of increasingly complex models. As an indication of the size of the field in Europe, a 2009 European Commission report formally identified "44 such tools in 26 countries" (Gál et al. 2009) developed by governments within Europe (including the United Kingdom) alone, each dealing with the unique complexities of the pension system within the country of development. Within the United States, three large-scale pension system simulation projects are underway: the Retirement Security Projection Model developed from state level with assistance from the office of the Governor of Oregon to national level by the Employee Benefit Research Institute throughout the 2000s (see VanDerhei 2011: Appendix 1); the Modelling Income in the Near Term (MINT) model developed by the Urban Institute and the Brookings Institution under contract from the national government's Social Security Administration Division of Policy Evaluation (Toder et al. 1999); and the DYNASIM3 model developed as an evolution of the aforementioned DYNASIM model by the Urban Institute, with support from various national government agencies (see Favreault & Smith 2004).

The prevalence of government-developed or government-supported models accords with reviews of the field on simulation-based pension policy research, which conclude that most existing simulation-based pension policy models have been "constructed within

the social security departments or the central statistical agencies of [the country of reference within the model] and they are being actively used to help guide policy reforms in pension systems, and to provide labour force and retirement income projections” (Kelly 2003; see also Dekkers & Belloni 2009: Table 1 for a list of known models in 2004 and their origin to further demonstrate this conclusion). As such, it is difficult to evaluate the state-of-the-art in pension policy modelling internationally owing to a lack of public information as to the design and methodology of such models. Further, difficulties arise in the comparison of Australian retirement income modelling with modelling undertaken overseas owing to the mandatory and private nature of Australian superannuation contributions, a feature of the Australian retirement income system that is not replicated in any other high-income OECD country in the world (Pallares-Miralles et al. 2012). However, the majority of European models were identified as utilising the simulation approach of “building up complete life histories of each individual in the dataset” (Gál et al. 2009) to model pension policy, as occurs within our model presented in this paper. Similarly, the US models mentioned above each utilise year-by-year transition probabilities to project the accumulation and consumption of retirement income across the lifecycle (see Smith 2012 for an example of this year-by-year methodology within the context of the DYNASIM3 model).

2.2 Simulation-based retirement income research in Australia

The current academic literature on modelling and simulating superannuation on an individual basis in Australia is limited. Since 1992 the Australian Treasury Retirement and Income Modelling Group (RIM) has regularly undertaken studies utilising its publicly unavailable models into retirement adequacy in Australia. For example, *The Adequacy Of Australian Retirement Incomes – New Estimates Incorporating The Better Super Reforms* (Rothman 2007) is an example of the application of RIM’s RIMGROUP model to examine the effect of contemporary superannuation policy reforms on retirement adequacy. However, RIM’s model operates at an aggregate rather than individual level to answer questions regarding the average effect of superannuation policy changes upon the entire population or a subsample of the population, without providing guidance as to the range of possible retirement outcomes. Further, the National Centre for Social and Economic Modelling (NATSEM) conducts superannuation research utilising its dynamic Australian population micro-simulation model (DYNAMOD) (see e.g. Kelly et al. 2001), but incorporates deterministic economic behaviour within

the simulation of fund returns rather than the more realistic stochastic behaviour that is captured by the model of this paper. Butt (2009, 2011) modelled defined benefit superannuation fund experience at an aggregate fund level through stochastic simulations in an Australian context, but with an academic focus limited to the management of closed defined benefit schemes.

Although Butt and Deng (2012) utilised a stochastic simulation approach to determine optimal investment strategies of individual defined contribution superannuation fund balances by Australian retirees at the point of retirement in the presence of a means-tested government pension, this work was limited in scope to post-retirement investment strategies rather than the simulation of the entire lifecycle of superannuation. Conversely, Basu (2008) utilised a simplified stochastic simulation approach (assuming deterministic salary inflation and random walk uncorrelated asset class investment returns) to assess the efficacy of lifecycle dynamic asset allocation of the pre-retirement superannuation fund account in achieving a particular wealth outcome at the point of retirement. The model presented in this paper extends these separate approaches to incorporate the pre-retirement superannuation accumulation phase in addition to the post-retirement withdrawal period examined in the Butt and Deng paper. This permits greater scope of the investigation of the whole of lifecycle of individual superannuation, including the impact of pre-retirement investment and economic decisions on the post-retirement outcomes of retirees.

Bell (2011) appears to have been the first to specifically address the question of mandatory defined contribution-based retirement income adequacy and range of outcomes across the entire lifecycle through stochastic simulation within Australia, although utilising a less rigorous model for the projection of Australian superannuation fund outcome by incorporating direct repetition of past behaviour of economic variables for a large portion of the simulation of the pre-retirement accumulation phase. Further, the Bell model assumes a complete lack of co-integration between price inflation and salary inflation. In this paper, such co-integration is specifically catered for within the model due to the interdependency for all the economic variables within the cascading model. The model presented here also caters for the investigation of the variation in superannuation asset allocation across the lifecycle (between domestic equities, international equities, domestic bonds, international bonds and cash investment), while the Bell paper instead simulates investment returns by using only return data of superannuation default options at an aggregate level. Price and Suryadi (2011) also sought to consider retirement outcomes through integration

of a stochastic investment simulation model similar to that in this paper into retirement outcome projections by the Australian Treasury. However, key elements of Treasury's projection models were not provided in their paper, and therefore it is difficult to make assessment of the validity of their approach and results.

3 METHODOLOGY

The SUPA model simulates the superannuation fund balance of a representative individual throughout their working and post-retirement life by modelling the four key contributors to the fund balance: (1) investment returns; (2) income levels; (3) withdrawal patterns; and (4) mortality projection. Treating these four components separately enables separate investigation of the impact of each of these four contributors on an individual's superannuation fund balance across their lifetime. It will also permit consideration of the impact of policy decisions upon individuals' superannuation fund balances and, in particular, the ability of individuals to support themselves with their own superannuation savings until death. By making use of stochastic forecasting for future scenarios, the model will be able to generate findings both in terms of the expected average outcomes and of identifying the range of likely retirement outcomes. At this stage, the model is capable only of projections on an annual basis; we are currently developing the model further to permit monthly projections in subsequent publications.

3.1 Investment outcome projection

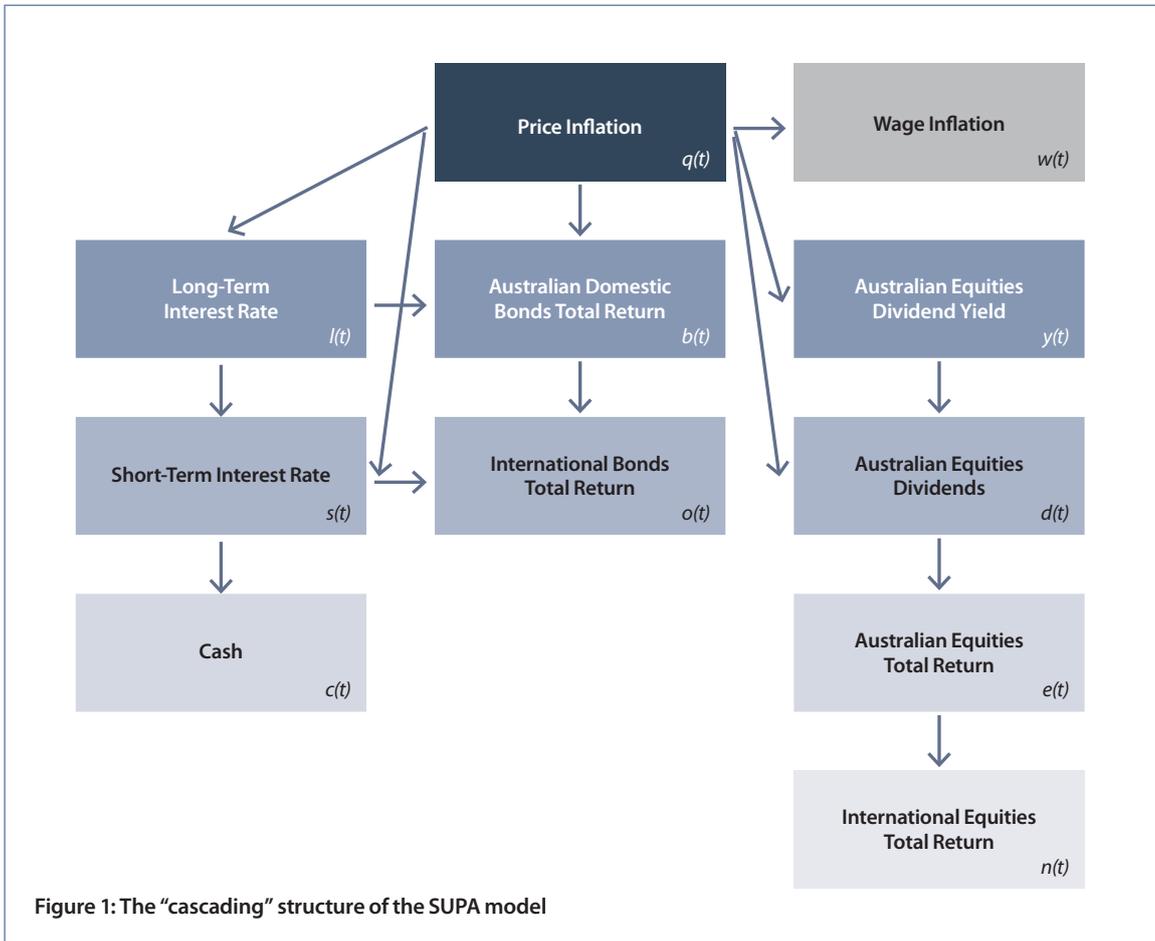
The investment outcome projection within the SUPA model simulates the returns achieved by superannuation assets throughout every year of an individual's lifetime. These returns are simulated by using a Monte Carlo numerical scheme. The projection method for long-term investment outcomes can be viewed as an extension of Butt's (Butt 2011) and Hibbert, Mowbray and Turnbull's (Hibbert et al. 2001, "the Hibbert paper") adaptations of the Wilkie cascade model (Wilkie 1986). The Wilkie stochastic asset model was first proposed to the United Kingdom's Institute of Actuaries in 1986 to project the long-term future behaviour of important elements of an economy (see also Wilkie 1995). In their paper, Hibbert, Mowbray and Turnbull suggested possible alterations of the original Wilkie model in the modelling of real interest rates, equity returns and inflation. Our model adopts the suggested alterations in real interest rate modelling by employing Hull-White models for both long-term and short-term interest rates (in accordance with the methodology employed in Chong 2007). It does not, however, adopt the suggested use of a two-factor

inflation model of the Hibbert paper, as it is unclear how this model may be calibrated by reference to the more objective market data alone. It is anticipated that subsequent development of the SUPA model will consider the incorporation of a regime-switching equity return model as suggested in the Hibbert paper and was previously adapted to Australian conditions in Harris (1999). Butt subsequently adapted the original Wilkie model to Australian conditions by incorporating "additional relationships at the foot of the Wilkie framework to model [the] variables" (Butt 2009: 7) of Australian domestic bonds, International (non-Australian) equities and international (non-Australian) bonds. The Butt model also removed inflation-linked bonds, since they are no longer issued in Australia, and avoided the modelling of property variables, which had been incorporated into the Wilkie model, due to "the paucity of Australian data available to fit such models." (Butt 2009: 7).

As in the stochastic investment models of both Wilkie (Wilkie 1986, 1995) and Butt (Butt 2009), price inflation and long-term interest rates are simulated individually and their performance "cascades" through the model to influence short-term interest rates, cash returns, domestic equity returns, international equity returns, domestic bond returns and international bond returns. This is achieved by modelling the relationship of the basis variables of inflation and short-term interest rates with the asset return variables on the basis of past relative economic performance, and assuming that these relationships will hold into the future in the longer term. Some variation is also introduced into the asset return variables through the incorporation of error terms calculated on a similar basis. The variables utilised in the model and their relationships are depicted in Figure 1.

Two key concepts underpin the use of the Wilkie model as a source of long-term investment projections. First, the model characterises each constituent financial variable as essentially an autoregressive process whose average returns revert to a longer-term mean, but in the short-term some noise around this mean (in addition to any influence exerted by other economic variables or factors) produces variation in its behaviour. The second idea, based upon established economic theory, is that the performance of all economic variables defined in the model is influenced to some degree by other variables in the model owing to inherent relationships within the economy: for example, the behaviour of price inflation "cascades" down the structure depicted above to influence other economic variables, which in turn affect the behaviour of economic variables further down the structure.

The Wilkie model combines the above two ideas. First, each variable is modelled on the basis of its own



past performance and past experience of its interaction with other relevant variables. For the basis variable of price inflation, this entails fitting an independent autoregressive time series model to this variable. Second, each variable must be pre-determined on the basis of the cascade structure, which advocates which other variables should be fit as independent variables alongside its own past individual performance as an independent variable. In Figure 1 arrows depict the "flow" of influence of variable behaviour on other variables within the structure – price inflation being the starting point of the cascade structure. Note that, for simplicity, international equity return and international bond return are modelled as "influenced" by Australian equity return and Australian bond return respectively; this is achieved through their simultaneous correlation rather than any delayed influence by domestic equity or bond returns.

The equations for each economic variable within the model are presented in Table 1 (see Butt & Deng 2012: Table B1); we have implemented the SUPA model in a computer program that automatically fits (calibrates) each of these equations and provides all fitted (calibrated) parameters necessary for projecting

future values of these economic variables. Each economic variable contains an error term ($\varepsilon_i(t)$), for variable i , as a white noise process of independently and identically distributed normal distributions with mean $\mu_{\varepsilon_i} = 0$ and standard deviation μ_{ε_i} .

The forecast accuracy of the SUPA simulation engine depends on the historic economic data used to calibrate the model. In order to produce more realistic simulations using the SUPA model, t years of past financial data should be selected that are reflective of immediate past Australian economic conditions. It is suggested that a suitable time period across which the model may be calibrated by using consumer price index, wage index, interest rate, stock index (local and international) and bond index (local and international) is the period 1993 to 2013. This period coincides with the commencement of inflation targeting by the Reserve Bank of Australia (Fraser 1993) and so has been a structurally consistent period economically and more reflective of the future economic context. It was also selected as it nearly exactly matched the longest period for which consistent data across all economic variables within the model was available, with international equities information available only commencing in

Table 1: Equations underpinning SUPA investment model

| Variable | Notation | SUPA model equation |
|-------------------------------------|----------|---|
| Price inflation | $q(t)$ | $q(t) = \mu_q(1 - \phi_q) + \phi_q q(t - 1) + \varepsilon_q(t)$ |
| Salary inflation | $w(t)$ | $w(t) = \psi_{w,2} q(t - 1) + \mu_w + \varepsilon_w(t)$ |
| Long-term interest rate | $l(t)$ | $l(t) = [l(t - 1) + (\Delta l(t - 1))] + q(t)$ where $\Delta l(t) = \kappa_l(\mu_l - l(t)) + \varepsilon_l(t)$ |
| Short-term interest rate | $s(t)$ | $s(t) = [s(t - 1) + (\Delta s(t - 1))] + q(t)$ where $\Delta s(t) = \kappa_s(l(t) - s(t)) + \varepsilon_s(t)$ |
| Cash | $c(t)$ | $c(t) = (s(t) + s(t - 1))/2$ |
| Domestic equity dividend yield | $y(t)$ | $(\ln[y(t)] - \ln[\mu_y]) = X_y(t)$ where $X_y(t) = \phi_y X_y(t - 1) + \varepsilon_y(t)$ |
| Domestic equity dividends | $d(t)$ | $d(t) = q(t) + \mu_d + \tau_{d,1} \varepsilon_y(t) + \tau_{d,2} \varepsilon_y(t - 1) + \varepsilon_d(t) + \theta_d \varepsilon_d(t - 1)$ |
| Domestic equities price return | $p(t)$ | $p(t) = \ln\left(\frac{D(t)}{\ln(1 + y(t))}\right) - \ln(P(t - 1))$ where $D(t) = D(t - 1)\exp(d(t))$ and $P(t) = P(t - 1)\exp(p(t))$ are the index values of $d(t)$ and $p(t)$ respectively |
| Domestic equities total return | $e(t)$ | $e(t) = p(t) + \ln(1 + \ln(1 + y(t)) \times [\exp(p(t))]^{0.5})$ |
| International equities total return | $n(t)$ | $n(t) = \mu_n + \psi_n e(t) + \varepsilon_n(t)$ |
| Domestic bonds | $b(t)$ | $b(t) = \psi_{b,1} l(t) + \psi_{b,2} l(t - 1) + \psi_{b,3} s(t) + \psi_{b,4} s(t - 1) + \varepsilon_b(t)$ |
| International bonds | $o(t)$ | $o(t) = \mu_b + \psi_b b(t) + \tau_b \varepsilon_q(t) + \varepsilon_o(t)$ |

1987. The model therefore currently incorporates the largest amount of Australian data available for parameterisation, a limitation not faced in the parameterisation of the original Wilkie model, which did not address international equities as an asset class.

Suitable data sources for each parameter within the current model (which focuses on general asset class returns) are provided in Table 2. It is suggested that specific commercially available assets in a given class may be parameterised by substituting returns data for such assets over the same period for that suggested above – it would be expected that any idiosyncratic risk associated with the specific product would be incorporated into the error term of the relevant asset class equation. Forecast results generated by the suggested data sources for the calibrated (parameterised) SUPA model are tabulated in Table 3 for each economic variable for a sample size of 10,000 simulations of 20 years length, alongside the equivalent results for the actual data. For example, the four parameters utilised within the model for the price inflation economic variable (μ_q , ϕ_q , μ_ε and σ_ε) were calculated by fitting to the time series data of annual

changes in the Consumer Price Index (all groups) between 1993 and 2013, as available online through the Reserve Bank of Australia website. Where an economic variable’s behaviour related to the behaviour of other economic variables within the investment projection model, the time series data of past performance of these other variables was incorporated into the fitting process alongside that of the key economic variable being considered.

Investment income within the SUPA model is also subject to taxation, whereby a percentage of the individual’s investment earnings are subtracted from fund income annually in accordance with applicable taxation regulations. At a basic level, this means that for each year of positive investment return the individual retains $(100 - x)\%$ of the investment return, where x is equal to the percentage taxable rate for investment earnings. The model currently incorporates a constant tax rate throughout the lifetime of the individual, but the model can be readily altered to incorporate variation for the taxation rate if necessary.

Further, the SUPA model permits the user to modify how the superannuation fund is invested

Table 2: Data sources utilised for sample parameterisation of SUPA investment model

| Variable | Index | Source |
|---------------------------------------|---|---------------------------------|
| Price inflation | Consumer Price Index (all groups) | Reserve Bank of Australia (RBA) |
| Salary inflation | Average Weekly Ordinary Time Earnings (all employees) | RBA |
| Long-term interest rate | 10-Year Australian Government Bond Yield | RBA |
| Short-term interest rate | 90 Day Bank Accepted Bills | RBA |
| Domestic equities (price return) | S&P/ASX200 Price Index | RBA |
| Domestic equities (total return) | S&P/ASX200 Accumulation Index | RBA |
| International equities (total return) | MSCI World ex-Australia Net Index (converted to \$A using the \$A/\$US exchange rate) | DataStream |
| Domestic bonds (total return) | UBS Warburg Composite Bond Index | DataStream |
| International bonds (total return) | Citigroup World Government Bond Index (hedged into \$A) | DataStream |

Table 3: Results generated by sample parameterisation of SUPA model and actual results

| Variable | Generated Return (% Per Annum) | Actual Return | Generated Standard Deviation | Actual Standard Deviation |
|---------------------------------------|--------------------------------|---------------|------------------------------|---------------------------|
| Price inflation | 2.54% | 2.54% | 1.46% | 1.42% |
| Salary inflation | 4.38% | 4.39% | 1.06% | 1.03% |
| Cash | 5.25% | 5.33% | 2.08% | 1.03% |
| Domestic equities (total return) | 8.39% | 8.74% | 14.92% | 14.46% |
| International equities (total return) | 4.02% | 4.33% | 19.44% | 18.84% |
| Australian bonds (total return) | 5.07% | 6.86% | 8.69% | 3.63% |
| International bonds (total return) | 6.24% | 7.64% | 7.01% | 3.29% |

toward the available asset classes: domestic equities, international equities, domestic bonds, international bonds and cash. The proportions are currently assumed to be rebalanced each year. Within the model, these allocations are inputs and can be modified on an annual basis at minimum.

3.2 Income projection

Projection of employment-related fund income within the SUPA model requires the projection of both the timing and magnitude of each contribution to an individual's superannuation fund. Currently, assumptions relating to the timing of these payments are deterministic: it is assumed that individuals commence employment at age 25 and maintain constant employment until age 65, when they retire. This assumption is self-evident as input for the SUPA simulation engine, and is easily alterable to any situation envisaged. In particular it does not reflect realistically the working pattern of females,

for example, where career breaks are common due to family commitments. For example, the income profile can be easily modified to accommodate this by either (a) entering an alternative wage inflation index into the calibration process to replicate the wage inflation of other cohorts; or (b) altering the fund projection model to incorporate alternative working patterns. The initial assumption currently used implies that the individual makes annual payments to their superannuation fund for exactly 40 years, after which the individual makes no further contributions to their fund and commences withdrawals until death or exhaustion of the fund balance.

Conversely, the size of annual contribution to the individual's superannuation fund throughout their employment has both deterministic and stochastic elements. Within the current model, the individual is assumed to contribute a constant proportion ("contribution rate") of their salary each year throughout their working career. This contribution

rate can be altered to different rates for specific future years or to vary dynamically if desired. Further, the individual's starting salary is set deterministically – for example, by reference to the current average graduate salary in Australia in 2013 of \$52,450.00 (Graduate Careers Australia 2013). Again, these inputs can be readily modified to reflect the profile of differentiated socio-economic segments of the society.

Stochastic variation in the contribution amount is introduced through the annual inflation of the wage inflation rate projected as an economic variable of the SUPA model. However, the level of inflation may be altered within the model to a deterministic constant annual rate or may be modelled as a stochastically independent economic variable if desired. The magnitude of the annual contributions made by an individual to their superannuation fund is therefore currently a function of their initial salary and the inflationary effect of wage index increases. It is anticipated that subsequent improvements of the income projection section of the model will incorporate substantially improved models for both working status (utilising a decrement-based approach) and wage level (utilising both salary inflation projection and real income projection based on factors such as age, education, gender and various other factors) building upon the work of Higgins (2010), Higgins and Sinning (2013) and Baldwin et al (2001). This work will utilise recently obtained data from the Household, Income and Labour Dynamics in Australia (HILDA) Survey – see Wooden and Watson (2007).

Further, contributions to superannuation funds within the SUPA model are also subject to taxation, whereby a percentage of the individual's contribution amount is subtracted from fund income annually in accordance with applicable taxation regulations. This means that for each contribution made to the superannuation fund the individual recipient retains $(100 - x)\%$ of this contribution, where x is equal to the percentage contributions tax rate for the individual. The model currently incorporates a constant contributions tax rate throughout the lifetime of the individual, but the model can be readily altered to incorporate variation in this rate if necessary.

3.3 Withdrawal projection

As with the projection of income, the projected annual withdrawals from the superannuation fund of an individual in the SUPA model contains a deterministic (but alterable) starting value and an annual inflation factor that may be deterministically or stochastically modified as desired. It is assumed within the model that the individual commences withdrawals immediately upon retirement at age 65 and continues withdrawing annually until death or

until the fund is exhausted. The starting value for withdrawals within the model is set by reference to the anticipated amount that an individual would require to withdraw from their superannuation fund. Currently, in the model this figure corresponds to the annual sum that has been identified by the Australian Superannuation Fund Association's "comfortable lifestyle" retirement standard, currently set at \$42,254.00 per year (ASFA 2014). This figure may be altered within the model to any value as required.

The second element of the withdrawal projection model is the inflation factor applied to each annual withdrawal to produce a nominal withdrawal amount for each year post-retirement. In the current model, the initial withdrawal figure is inflated each year in accordance with price inflation as projected under the investment outcome projection model. However, the model permits the incorporation of a deterministic constant rate of inflation for the withdrawal amount. In addition, it is possible to incorporate a different level of cost inflation in retirement to include anticipated or unanticipated costs at older ages (e.g. those associated with aged care requirement).

3.4 Mortality projection

The SUPA model also has the capacity to study mortality-related questions in superannuation, such as whether an individual can expect to outlive their superannuation fund needs. This is achieved through the incorporation of a stochastic mortality projection model, where the length of each simulated life is the aggregate result of a series of year-upon-year conditional survival probabilities. These conditional survival probabilities are projected into the future on the basis of past mortality rates in accordance with the Lee-Carter mortality model (Lee & Carter 1992). The Lee-Carter mortality model was selected for incorporation into the SUPA model because it is "now the dominant method of mortality forecasting" (Booth & Tickle 2008) despite its potential underestimation of variation in projected death probabilities due to parameter and model error over and above process error (Renshaw & Haberman 2008). It is anticipated that alternative mortality models and approaches to the Lee-Carter methodology (see e.g. Li 2014) will be integrated into subsequent development of the SUPA model; a comprehensive review of alternative mortality models can be found in Booth and Tickle (2008). For further detail on the projection method for mortality rates, the reader is referred to the paper introducing the Lee-Carter model (Lee & Carter 1992). As an example, from age 25, the probability of an individual life surviving to age 30 is the product of 5 separate binomially distributed variable outcomes, each of which had probability of survival of $(1 - q_{x,t})$ where

Table 4: Equations for projection of individual lifetime within SUPA model

| Step | Purpose | Equation |
|------|---|---|
| 1 | Projection of all $q_{x,t}$ mortality rates | See Lee & Carter (1992) |
| 2 | Probability of individual being alive at age 25 (time 0) (state 1 is for being alive, state 0 is for being dead) | $\Pr(A_{25,0} = 1) = 1$ |
| 3 | Probability of individual being alive at age 26 (time 1) | $\Pr(A_{26,1} = 1 A_{25,0} = 1) = (1 - q_{25,0})$ |
| 4 | Determine whether the individual is alive at age 26 and time 1 | Produce a random number R: $\begin{cases} \text{if } R \leq (1 - q_{25,0}), \text{ let } A_{26,1} = 1 \\ \text{if } R > (1 - q_{25,0}), \text{ let } A_{26,1} = 0 \end{cases}$ |
| 5 | If $A_{26,1} = 0$, individual has died at age 26 If $A_{26,1} = 1$, individual is alive at age 26 and continue life projection | |
| 6+ | Repeat steps 3 to 5 for each year forward until $A_{25+t,0+t} = 0$. | |

Table 5: SUPA model fund balance equations

| Element | Equation |
|-------------------------------|---|
| Total fund balance = | $F(x, t) = F(x, t - 1) + C(x, t) - W(x, t) + I(x, t)$ |
| Contributions $C(x, t)$ | $C(x, t) = a_{x,t} i_{x,t} (1 - t_{x,t})$ where $a_{x,t}$ = super contribution rate at age x plus time t $i_{x,t}$ = income at age x plus time $t = i_{x,t-1} \times \exp(w(t - 1))$ where $i_{x,0}$ = initial career salary $w(t)$ = salary inflation at time t $t_{x,t}$ = contributions tax rate at age x plus time t |
| - Withdrawals $W(x, t)$ | $W(x, t) = \begin{cases} 0, & (\text{where } x + t < \text{retirement age}) \\ W(25,0) \times \prod_{n=1}^t \exp(q(n - 1)), & (\text{where } x + t \geq \text{retirement age}) \end{cases}$ where $W(x, 0)$ = initial withdrawal amount $q(t)$ = price inflation at time t |
| + Investment income $I(x, t)$ | $I(x, t) = [F(x, t - 1) - W(x, t)] \times \text{returns}_{x,t}$ where $\text{returns}_{x,t} = (1 - \text{tax}_{x,t}) \times \sum_{z=0}^5 \text{alloc}_{z,x,t} \times \exp(r_{z,x,t})$ $\text{alloc}_{z,x,t}$ = portfolio allocation in asset class z at age x plus time t $r_{z,x,t}$ = return in asset class z at age x plus time t $\text{tax}_{x,t} = \begin{cases} 0, & (\text{where } \text{returns}_{x,t} \leq 0) \\ \text{investment income tax rate at age } x \text{ plus time } t, & (\text{where } \text{returns}_{x,t} \geq 0) \end{cases}$ |

$q_{x,t}$ is the probability of death (the mortality rate) at age x for time step t . In equation form, the projection of the lifetime of an individual (starting at age 25) is shown in Table 4.

By following the iterative simulation scheme as illustrated in Table 4, we can independently project and simulate the lifespan of each individual such that, for each year of age x at time step t , an individual is either alive ($A_{x,t} = 1$) or dead ($A_{x,t} = 0$).

3.5 Summary of fund balance projections

In summary, the fund balance of an individual consists of three elements: (1) contributions; (2) investment income; and (3) withdrawals. The equations for determining the contributing amount of these three elements to the fund balance on an annual basis, as well as equations for calculating the three elements, are provided in Table 5. These equations assume that the individual commences their career ($t = 0$) at age 25.

In relation to contributions, it is assumed that each individual's superannuation income (as a proportion

of annual salary) comes into the fund at the end of each year, and it is assumed that the individual's first annual salary is given and each later year's salary grows by the previous year's salary inflation. Contributions of each future year are also subject to contributions tax such that a proportional tax is payable on (subtracted from) any contribution made to the individual's superannuation fund. We have assumed a simple tax rate for contributions for the current paper; subsequent developments of the model will endeavour to incorporate more complex formulae for contributions, allowing for concessional and non-concessional additional contributions and the operation of existing contributions caps. These will be included through the splitting of the contribution calculations into these various sub-categories.

In relation to withdrawals from the fund from retirement age onwards, it is assumed that withdrawals come out of the fund at the start of each year and it is assumed that the "initial withdrawal amount", the amount that would be withdrawn if the individual retired immediately upon commencement of the projection, is given. Each later year's withdrawal grows by the previous year's withdrawal inflation such that, by the age of retirement, the withdrawal amount is the initial withdrawal amount inflated by the price inflation experienced by the individual between the date of career commencement and the date of their retirement. For the purposes of this paper, social security arrangements have not been incorporated into the presented model; this work will be published in a subsequent paper whereby an individual's withdrawal at a given age and given time will be reduced by the social security entitlements of the individual at that point. It will then be assumed that the individual supplements their social security entitlements through sufficient withdrawal from their superannuation balance to reach their aggregate withdrawal amount.

In relation to investment returns experienced by the fund, the investment income earned by the fund differs according to whether the individual is working or retired. In a working year, investment returns are only obtained upon the individual's previous year's fund balance because the additional contribution in that year occurs at the end of the year. In a retirement year, investment returns are obtained upon the individual's previous year's fund balance LESS the amount the individual is assumed to have withdrawn at the commencement of that year. In both circumstances, the investment income is also subject to taxation such that no taxation is payable in years of negative investment income and a proportional tax is payable on (and subtracted from) any year's positive investment income to the individual's superannuation fund balance. The

current model incorporates a flat investment income tax on the portfolio as a whole; it is anticipated that a more detailed model for investment income taxation will be developed in subsequent publications to separate dividends and capital gains for taxation purposes.

4 CASE STUDY: THE IMPACT ON SUPERANNUATION FUND BALANCES FROM THE NEW COMPULSORY SUPERANNUATION RATE OF SEPTEMBER 2014

This case study focuses on 2014 legislative changes to mandatory superannuation contribution rules by the federal government. This study will use the SUPA model to study retirement outcomes under both the newly legislated superannuation contribution rate regime and the previous schedule. These results will provide some insight as to the accuracy of recent statements made by relevant participants in the politically charged superannuation debate.

The SUPA model is firstly calibrated by relevant economic data from the years 1993 to 2013, a period selected as the longest recent period for which the economy has been structurally consistent since the introduction of the Reserve Bank of Australia's inflation targeting policy of mid-1993. In the SUPA model, we incorporate the co-dependent behaviour of seven variables (factors) of the Australian economy relevant to superannuation research: (1) price inflation; (2) wage inflation; (3) Australian stock market returns; (4) international stock market returns; (5) Australian bond returns; (6) international bond returns; and (7) Australian cash investment returns. Once the SUPA model is calibrated by the historical data of the seven economic variables, the SUPA simulation engine can generate a large number of probable future paths of these economic variables, thus, we can project a range of retirement outcomes achievable through an individual's superannuation fund given certain assumptions relating to the individual's behaviour. These assumptions are:

- The individual's rate of contribution to the fund relates to the percentage of weekly salary. For the purposes of this study, the assumption is varied to match both the pre-2014 schedule of compulsory superannuation contributions and the "new" schedule – these are provided in Table 6.
- The retirement age of the individual is assumed to be 65 years old.
- The career commencement age of the individual is assumed to be 25 years old.
- The individual is assumed to withdraw (at the

Table 6: Comparison of “old” (pre-2014) and “new” (2014) compulsory superannuation contribution schedules

| Year | 2014–2015 | 2015–2016 | 2016–2017 | 2017–2018 | 2018–2019 | 2019–2020 | 2020–2021 | 2021–2022 | 2022–2023 | 2023–2024 | 2024–2025 | 2025–2026+ |
|------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|------------|
| Pre-2014 | 9.5% | 10% | 10.5% | 11% | 11.5% | 12% | 12% | 12% | 12% | 12% | 12% | 12% |
| New (2014) | 9.5% | 9.5% | 9.5% | 9.5% | 9.5% | 9.5% | 9.5% | 10% | 10.5% | 11% | 11.5% | 12% |

Table 7: Explanation of basic statistics produced for purposes of case study

| Statistic | Explanation |
|---|---|
| Average fund length | $\frac{\text{Aggregate number of years across all sims}}{\text{Total number of sims}}$ |
| Average fund level at mid-2025 (current \$) | $\frac{\text{Sum of fund levels at } (t = 10) \text{ across all sims}}{\text{Total number of sims}}$ |
| Average fund level at retirement age (current \$) | $\frac{\text{Sum of fund levels at } (t = 40) \text{ across all sims}}{\text{Total number of sims}}$ |
| Probability of pre-death fund ruin | $\frac{\text{Number of sims for which } t(\text{zero balance}) < t(\text{death})}{\text{Total number of sims}}$ |
| Expected number of years of pre-death fund ruin (of those ruined) | $\frac{\text{Aggregate number of years between } t(\text{zero balance}) \text{ and } t(\text{death})}{\text{Number of sims for which } t(\text{zero balance}) < t(\text{death})}$ |

beginning of each year) from their retirement age onward an annual amount equivalent to the ASFA comfortable living income requirement, which is \$42,254.00 per annum at 2014, inflated in accordance with projected price inflation rate (CPI) until death.

- The individual is assumed to receive an annual salary (at the end of each working year) beginning at the average graduate starting salary in 2013 of \$52,450.00 and growing with the SUPA projected wage inflation until retirement at the age of 65.
- Individual mortality is projected by utilising the Lee-Carter mortality model as applied to Australian Bureau of Statistics mortality data (Human Mortality Database 2014), and by including projection for longevity improvements based upon this model.
- It is assumed for the purposes of this study that no superannuation contributions tax or investment earnings tax are applied to the individual.
- The summary output from calibrating the SUPA model by fitting to relevant economic data sets from the Australian Bureau of

Statistics and Thomson Reuters Datastream for the average returns across the projected 85 year period can be seen in Table 3.

4.1 Outputs from Modelling Work

By using the calibrated SUPA model, we can generate detailed scenario outcomes with regards to potential future paths of these key economic variables. The following basic statistics can be readily provided by the model at this stage, see Table 7.

To understand the potential impact of the 2014 government amendment, we can compare the output from the model under both the previous compulsory contribution rate schedule and the new schedule using the output statistics currently available from the SUPA model in Table 8. Further development of the model will permit the inclusion of other stochastic measures of retirement experience, including statistics relating to investment performance (such as the likelihood of negative investment returns in any given year or achievement of a given long term investment objective) and retirement outcomes (such as the permitted withdrawal amount to achieve a given probability of avoiding fund ruin or the probability of obtaining a given fund balance at given ages).

Table 8: Output statistics from SUPA model for Compulsory Superannuation Rates

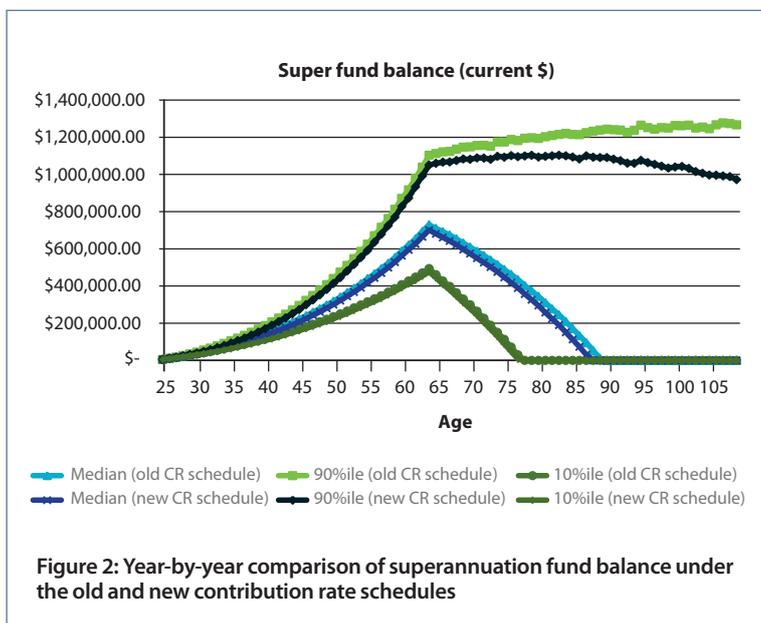
| Statistic | Old CR structure | New CR structure | Difference |
|---|----------------------------------|----------------------------------|---------------|
| Average fund length (years) | 27.60 | 26.95 | -0.65 |
| Fund balance at mid-2025 (current \$) | \$87,496.85 | \$77,007.45 | -\$10,489.40 |
| Mid-2025 balance (current \$) 95% confidence interval | (\$64,631.59, \$117,013.00) | (\$56,962.52, \$103,159.66) | |
| Fund balance at mid-2025 (nominal \$) | \$115,675.90 | \$101,809.24 | -\$13,866.66 |
| Mid-2025 balance (nominal \$) 95% confidence interval | (\$85,863.11, \$154,030.30) | (\$75,601.62, \$135,769.56) | |
| Fund balance at retirement at 65 (current \$) | \$770,984.65 | \$739,325.56 | -\$31,659.09 |
| Retirement balance (current \$) 95% confidence interval | (\$406,852.64, \$1,373,364.29) | (\$394,045.90, \$1,303,677.16) | |
| Fund balance at retirement at 65 (nominal \$) | \$2,147,686.73 | \$2,045,574.45 | -\$102,112.28 |
| Retirement balance (nominal \$) 95% confidence interval | (\$1,056,221.57, \$4,027,638.39) | (\$1,087,710.75, \$3,670,255.45) | |
| Probability of super funds' ruin before death | 26.92% | 29.73% | +2.81% |
| Expected number of years between ruin and death | 7.94 | 8.08 | +0.14 |

4.2 Case study comments

The figures in Table 8 indicate that, given the assumptions of the SUPA model, the post-retirement duration of the superannuation fund of an individual will fall by approximately one year, and the probability of them running out of money to support their retirement prior to death will increase by nearly 3%. Furthermore, at retirement the 25-year-old individual commencing their career in 2014 can expect to have

approximately \$31,700.00 less in their superannuation fund in current dollar terms, or approximately \$102,100.00 less in terms of nominal dollars on retirement. Finally, the 25-year-old individual commencing their career in 2014 can expect to have approximately \$10,500.00 less in current dollar terms or approximately \$13,900.00 less in nominal dollar terms by the middle of 2025. Recently, Industry Super Australia stated that “For an average income earner, aged 25, the delay in the SG [superannuation guarantee rises relative to the previous schedule] will cost them around \$100,000 over their working life (\$36,000 in today’s dollars)” (Industry Super Australia 2014); the Australian Labor Party also released a press announcement stating that “a 25-year-old Australian earning \$55,000 a year will be more than \$9000 worse off by 2025” (Crowe 2014) as a result of the 2014 legislative changes. In this paper, we do not intend to comment on any discussions with commercial or political objectives. We only note the figures quoted by the two organisations are in the same order of magnitude as calculated by the SUPA model.

We can also see the impact of the introduction of the new compulsory contribution rate schedule visually in the charts below. First, Figure 2 provides a comparison of the superannuation fund balance (in 2014 dollars) of a case study individual under both the old and new contribution rate schedules. Three points are provided at each age for either scenario: the median outcome of 10,000 simulations, the 90th percentile



highest account balance and the 10th percentile highest account balance.

It is noticeable in the above comparison that the change in contribution rate has a larger impact on retirement length than on retirement balance: the apparently small gap in median retirement outcome grows in retirement such that the median individual under the old contribution rate schedule has \$53,533 left in their account when the median new schedule individual exhausts their balance at age 88. The impact upon the lower percentile of balances is less pronounced, with individuals under each scenario exhausting their balances at age 78 and retiring with almost identical balances (\$493,627 under the old schedule as opposed to \$476,389 under the new schedule). The impact upon the higher percentile is far more pronounced, as the change in contribution rates appears to cause a significant divergence in retirement outcome. Under the old schedule, it would appear that those under the old schedule at the 90th percentile of retirement age balance have sufficient funds to withdraw to their needs and still retain enough to improve their balance through investment returns throughout retirement, while those in a similar position under the new schedule appear to retire with balances just below the necessary level to achieve this. Under each scenario, this would appear to only affect the capacity of an individual to bequest to family at death, with both individuals avoiding super fund exhaustion throughout retirement.

Figure 3 provides a static perspective on retirement outcomes under the SUPA model. Here, the cumulative density functions of probability of obtaining a particular retirement age fund balance under both the new and old contribution rate schedule scenarios are provided. For example, under the old contribution rate schedule, the probability of obtaining less than \$1,000,000 at retirement age is 83.9% or conversely the probability of exceeding this amount is 16.1%. Under the new schedule these figures are 87.0% and 13.0% respectively. It can be seen from the chart that, for all desired retirement fund balance levels, the change from the old contribution rate schedule to the new contribution rate schedule leads to lower probabilities of exceeding the required fund level at retirement. Clearly, the switch in contribution rate schedules is projected to cause worsened retirement outcomes under the SUPA model.

5 CONCLUSIONS

There exists a substantial academic literature assessing the adequacy of the Australian retirement income system, both qualitatively and quantitatively (see e.g. Butt & Deng 2012). In general, however, quantitative

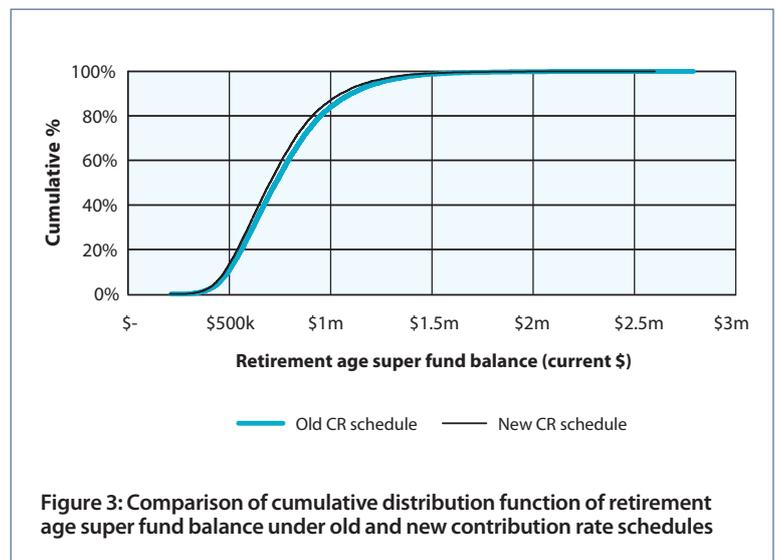


Figure 3: Comparison of cumulative distribution function of retirement age super fund balance under old and new contribution rate schedules

modelling on the adequacy of retirement income has mainly relied on using deterministic projections of future returns and expenditures. These fixed projected income returns and expenditures do not capture the uncertainty in their estimates. By contrast, using stochastic modelling approach to simulate retirement income and expenditure can provide a far more realistic estimate of possible future outcomes in the superannuation system. Although a stochastic modelling approach, such as the SUPA model, is more complex and not easy to utilise, such modelling methodology is now increasingly being referenced and adopted in academia and the industry. This paper seeks to outline such an approach and outline the vast potential of stochastic modelling in informing the current superannuation debate in Australia. As more countries move into a defined contribution system to fund retirement (for example the United Kingdom’s recent removal of compulsory annuitisation), the approach of this paper, which focused on Australia, will become increasingly relevant to the retirement income policy debate in the United States, United Kingdom and other jurisdictions.

This paper outlined the SUPA model’s output as a product of stochastic projections of investment returns, fund income, fund withdrawal and mortality. The case study performed in this paper has demonstrated the value of such a stochastic modelling approach as an analytical tool in studying the 2014 legislative changes affecting future mandatory superannuation contribution rates and their potential impact on future superannuation fund adequacy. The current SUPA model is adequate for assessing and addressing questions raised in the debate on the retirement income adequacy of the Australian superannuation system. However, the structure of the SUPA model is flexible to

allow for easy extension to incorporate new economic variables and relationships. We expect the SUPA model will be further developed to incorporate Australia's means-tested government age pension and associated taxation arrangements (such as those related to transition to retirement provisions and the influence of home ownership upon retirement outcomes) to provide additional realism and reflect more completely the complexity of Australia's superannuation retirement income system.

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A “simple” stochastic model for longevity risk revisited through bootstrap

XU SHI AND BRIDGET BROWNE



Xu Shi



Bridget Browne

ABSTRACT

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 paper we will first modify 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, we present simulation of cash flows for a sample annuity product. Lastly, we compare this model with a recently published stochastic mortality forecast and current regulatory capital requirements in Australia. Our method results in very similar prediction intervals to the recent forecast for age-specific mortality rates. We further find that the current approach to determining regulatory capital requirements may not be meeting the intended objective.

KEYWORDS

stochastic mortality modelling; annuities; longevity risk; bootstrap

1 INTRODUCTION

Browne et al. (2009) described a simple model developed by Koller (2011) to turn any deterministic mortality scenario into a stochastic model. This model is intuitive and easy to implement. However, some of the assumptions imposed in this model do not hold for all datasets. In this paper the authors take the same model structure but implement it in a non-parametric style, hence rendering it more broadly applicable.

The paper first introduces longevity risk as faced by life insurers and others. We then outline the original stochastic model and point out some of its deficiencies before introducing our modifications to adapt the model when the need arises. Furthermore, we elaborate on the choices for future variability structure. Next, we show numerical examples using Australian female data. We conclude with comparisons to a recently published stochastic mortality forecast and current Australian regulatory capital requirements for longevity risk.

2 LONGEVITY RISK

Ongoing sustained reductions in mortality rates have been one of humanity's greatest achievements over the course of the twentieth century and into the twenty-first. These reductions have resulted in an unprecedented extension in average human lifespan, which is to be celebrated, although the consequences present challenges for some segments of society. One of these challenges is longevity risk: the potential downside or negative aspects of this wonderful outcome. For an individual, this risk is both systemic and idiosyncratic, that is, the risk that they may outlive their savings, for example, as a result of general extensions in lifespan or due to the degree of variability in any one individual's age at death.

In this paper, however, we are concerned with longevity risk at an aggregate level: that of the life insurer with a large portfolio of annuities, a pension fund with a large number of pensioners or a national pension system funded by the state. Here the individual idiosyncratic risk becomes negligible due to the law of large numbers¹ and our principal concern is the systemic risk at population level of changes in mortality well beyond those anticipated in their best or central estimate of trends. It is this aspect of longevity risk that leads insurers, for example, to set aside capital to deal with the potential extra cost associated with a much extended lifespan.

3 THE ORIGINAL MODEL AND MODIFICATIONS

In this section we describe the original model and the modifications we propose.

3.1 The original model

To be complete, we first outline the model proposed by Koller (2011) and described by Browne et al. (2009): interested readers are referred to their papers. Let $q_{x,t}$ and $\hat{q}_{x,t}$ be the observed and expected mortality² at age x in year t , respectively. The model structure is expressed in the following equation:

$$q_{x,t} = \hat{q}_{x,t} \times C_t + \varepsilon_{x,t},$$

where $t \in \mathbb{N}_0 = \{0, 1, \dots\}$, C_t is a stochastic process which models the ratio of $q_{x,t}$ to $\hat{q}_{x,t}$ and $\varepsilon_{x,t}$ is the idiosyncratic (i.e., individual) random noise, which does not concern this paper. It is assumed that C_t and $\varepsilon_{x,t}$ are independent of each other. Furthermore, the stochastic process C_t is defined as follows:

$$C_t = e^{X_t} \times C_{t-1}, C_0 = 1,$$

where $(X_t)_{t \in \mathbb{N}_0}$ are assumed to be independent and identically distributed normal random variables with mean μ and variance σ^2 . Equivalently, $(e^{X_t})_{t \in \mathbb{N}_0}$ are assumed to be independent and identically distributed lognormal random variables. Here the lognormal distribution is chosen since past experience suggests that C_t is skewed to the right, that is, we expect to see very large e^{X_t} occasionally, leading to large upward movement in C_t .³ To ensure that the simulated mortality follows the given central estimate, it is reasonable to require that $\mathbb{E}[e^{X_t}] = 1$. Note that this requirement imposes a constraint on the two parameters μ and σ^2 since $\mathbb{E}[e^{X_t}] = e^{\mu + 0.5\sigma^2}$. This constraint implies that only one of the two parameters is needed to calibrate the model, and the previous authors chose σ^2 . To estimate σ^2 the authors first smoothed an observed mortality surface and then compared the smoothed mortality with crude mortality to determine the residual variability, i.e. σ^2 . The examined X_t passed the Jarque-Bera test for normality (Jarque and Bera, 1980).

It should be noted that the model described above still falls into the category of extrapolative methods in the sense that it assumes that the past pattern of variability will continue into the future. However, the central/best estimate being used might be derived from other methods, such as expectation or explanation methods. Effectively in this process we do not need

1 These institutions may face some residual idiosyncratic risk: that of heterogeneity in the sub-groups that make up their total population. This is usually dealt with at base mortality level (Madrigal et al., 2011, Richards, 2008a).

2 When forecasting, this expected value is the best/central estimate that is treated as a given.

3 This amounts to a drastic increase in mortality rates, for example, the mortality spike during the Spanish flu epidemic in 1918.

to know the model from which the best estimates for future mortality are derived. The smoothing models are examined only with respect to their adequacy for describing the underlying process of the past and thus identifying the variability that still remains in the mortality process. This approach relies on the belief, held by most forecasters, that we have the "best" outlook for the future, so in our case the variability from the past is indeed a reasonable estimate that is applicable for the future.

3.2 Modification

The original model is simple and easy to implement (Huang and Browne, 2014). However, it may be the case that the key assumption of normality for X_t does not hold for the dataset at hand such as Australian female data (cf. Section 4). In this paper, we modify the previous model to address this concern and in doing so increase its applicability.

As a first possible solution to address non-normality, it is common to transform X_t , for example, by taking square root, cubic root or natural logarithm. Transformation methods, however, may not always achieve the desired objective. In the current case, X_t takes negative values, thus square root and logarithm do not make sense. Further it can be difficult to justify why a certain transformation actually works even if a technically satisfactory approach is found.

As an alternative, we take a non-parametric or data-driven approach to the problem. In such an approach, we do not specify any distribution for X_t . Therefore, the method is distribution-free. In particular, we will focus on one non-parametric method, namely, the bootstrap method. The bootstrap method can improve the inference by generating more data than initially available through the following re-sampling scheme. With the observed values x_1, \dots, x_n , we can create realisations of the random sample X_1^*, \dots, X_m^* by simply randomly drawing m values from the collection $\mathcal{X} = \{x_1, \dots, x_n\}$, i.e., treating \mathcal{X} as the population, with replacement. This bootstrap process is repeated B times, where B is sufficiently large for the purpose at hand. This gives rise to the re-sampled datasets: $\{X_{11}^*, \dots, X_{m1}^*\}, \dots, \{X_{1b}^*, \dots, X_{mb}^*\}, \dots, \{X_{1B}^*, \dots, X_{mB}^*\}$. From each resampled dataset, we construct random realisations $\{C_{11}^*, \dots, C_{m1}^*\}, \dots, \{C_{1b}^*, \dots, C_{mb}^*\}, \dots, \{C_{1B}^*, \dots, C_{mB}^*\}$, and

in turn, we calculate mortality rates, survival rates and, eventually, the cash flows associated with an insurance product.

Note that, in addition to requiring sufficient observations to justify the approach, X_t should be mutually independent for the bootstrap to be valid:⁴ this will be tested in our numerical example. This method is also intuitive and straightforward to implement and similarly provides a distribution for the demographic items or cash flows of interest, which makes it possible to determine capital requirements by reference to a certain percentile. Interested readers of the bootstrap method are referred to Efron and Tibshirani (1993).

Other minor modifications over the original work are an improved examination of the normality of X_t by inspecting QQ plots instead of Jarque-Bera tests and strengthened justification of the age-independence of X_t by fitting regression models instead of visual inspection of graphics.

Moreover, the original model used a single realisation of X_t for all ages in any given projection period. In addition, in this paper we consider the case that X_t is unrelated to both age and time, i.e. simply a random variable X , and we discuss the implications of these two possible structures in the next section.

4 A NUMERICAL EXAMPLE

In this section, we present a numerical example based on the female population of Australia. The dataset is from the Human Mortality Database (2014). We restricted ourselves to ages between 55 and 89⁵ (inclusive) over the period from 1954 to 2008.⁶ That is, we considered one mortality surface (only for females⁷) of 35 ages with 55 calendar-year observations. The crude mortality improvement rate from year t to year $t+1$ for a given age x is defined as $\left(1 - \frac{q_{x,t+1}}{q_{x,t}}\right) \times 100\%$ and the resulting contour plot is shown in Figure 1. By this definition, positive values for the improvement rate indicate that the mortality rate is smaller compared with the previous year and vice versa.

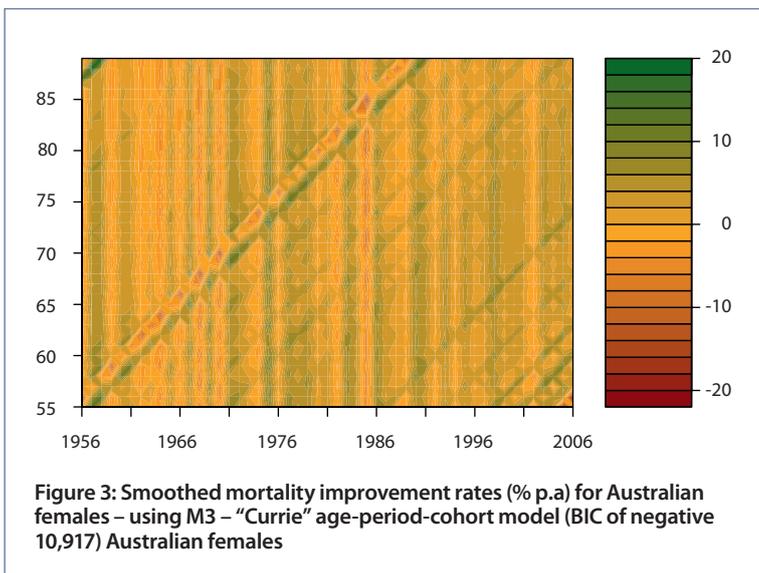
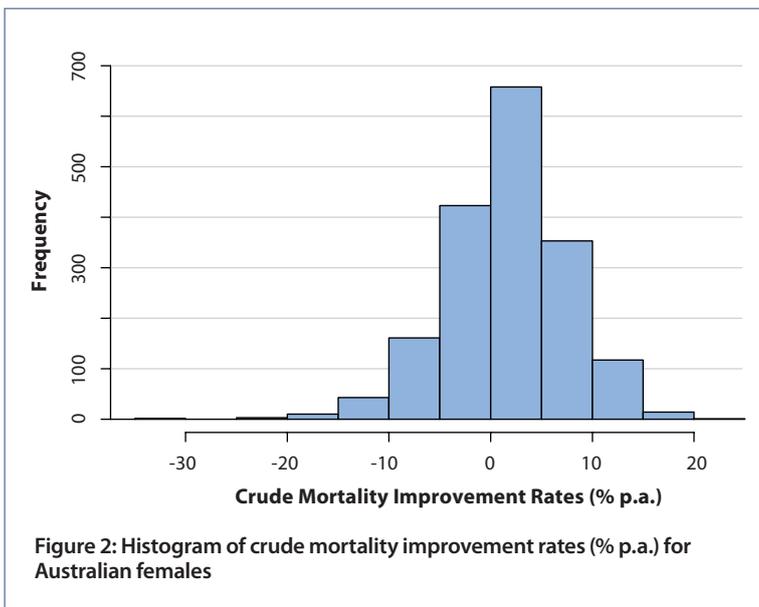
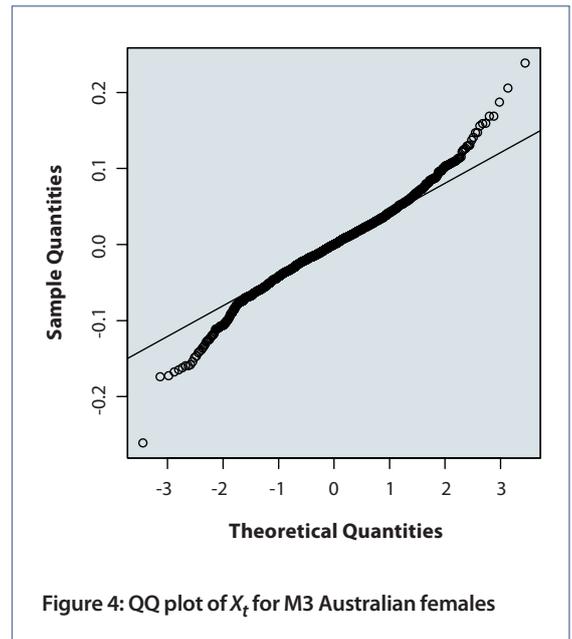
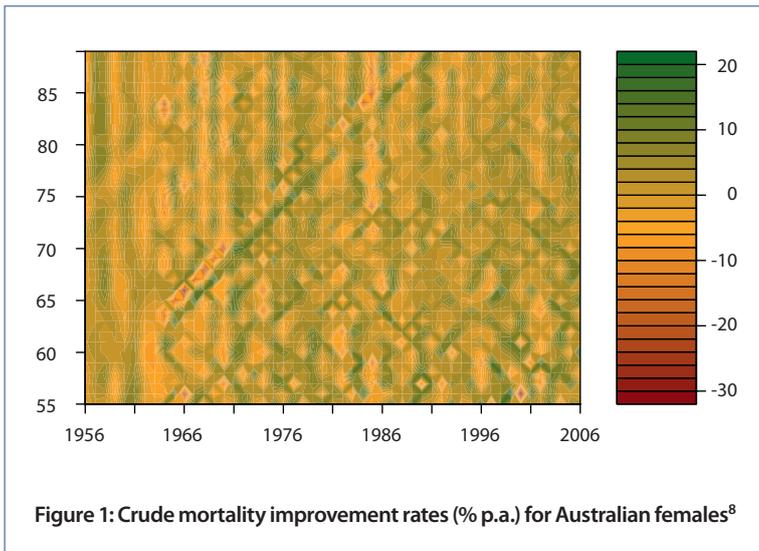
As Figure 1 shows, mortality at each age fluctuates from year to year. In general mortality improves more than it deteriorates over the period under consideration, as illustrated in Figure 2. In addition, a cohort effect is

4 Bootstrap techniques have been used before in considering variability in mortality forecasts, as summarized and applied by Liu and Braun (2010). Interestingly their paper moves to a block bootstrap approach precisely because in their case they find that the residuals being modelled do not meet the mutually independent condition.

5 The upper limit of 89 is directly imposed by software constraints, but is due indirectly to scarcity of data at older ages. It means we make some rather strong assumptions regarding X_t in that we assume that at more advanced ages the distribution is the same as for lives aged between 55 and 89. This assumption is clearly open to further research.

6 Here we take one or two more years of data in order to avoid edge effects in the smoothing procedure.

7 The same procedure would apply to a male mortality surface of course.



clearly present, as indicated by the diagonal patterns. Hence, it is desirable to see these features in the contour plot of smoothed mortality improvement rates.

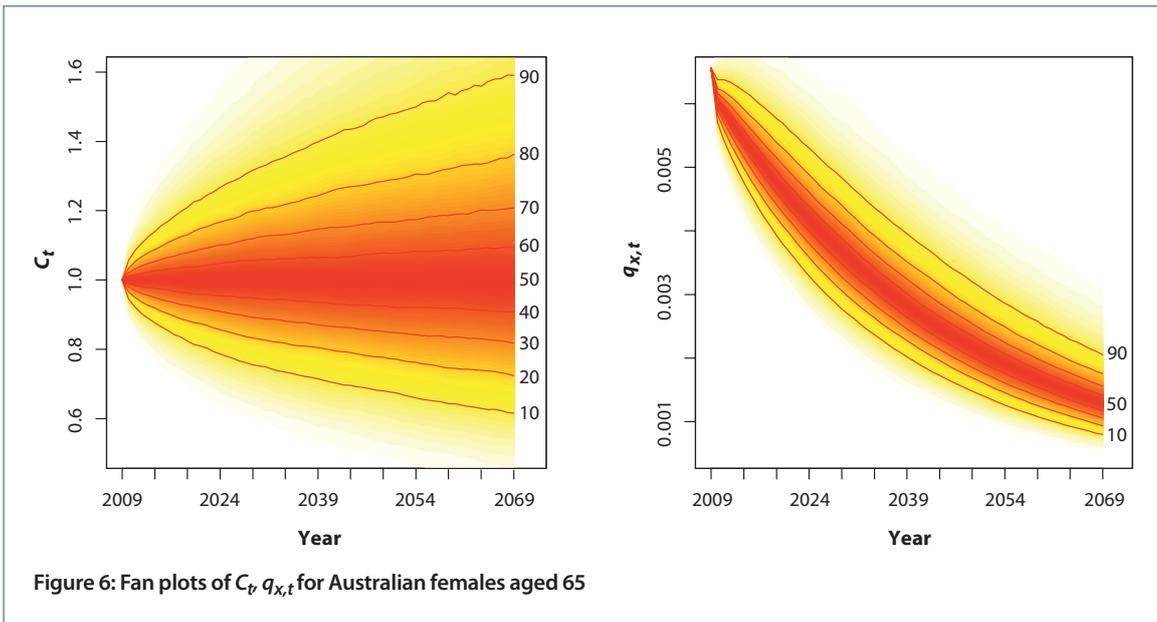
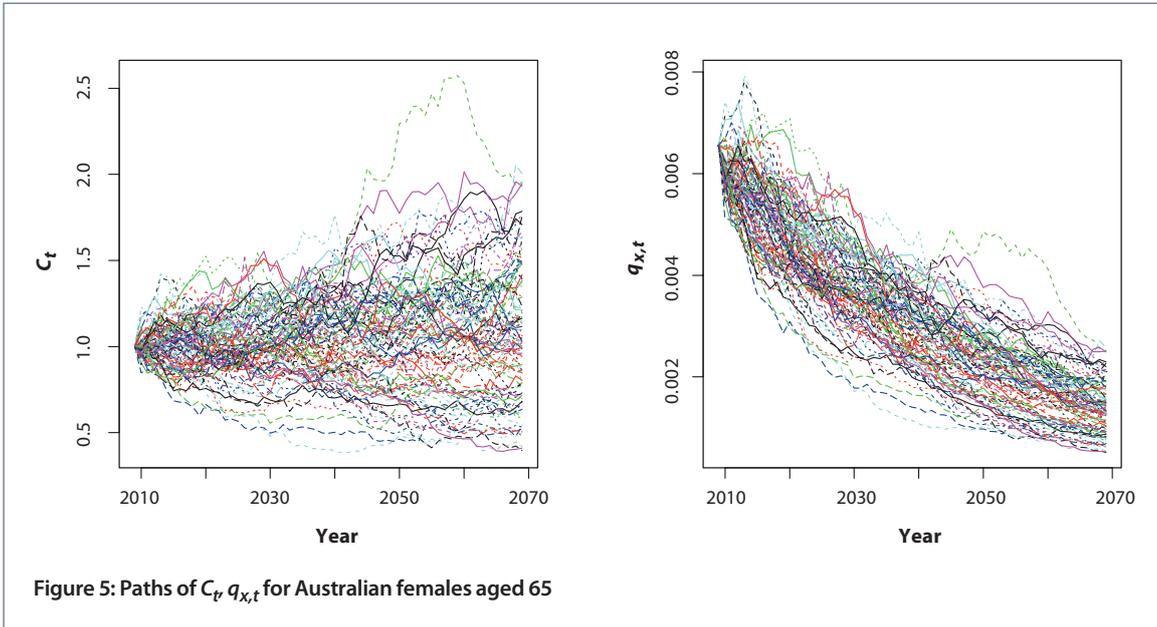
In this paper, we have restricted the smoothing techniques to those presented in LifeMetrics (Coughlan et al. 2007). For similar reasons to those outlined in Browne et al. (2009), we choose M3 as the smoothing method, although we applied more candidate models and performed additional testing (see the Appendix for detail on the process followed). The mortality improvement rates calculated from the expected/smoothed mortality are plotted in Figure 3. These closely resemble the plot of the crude rates.

With the fitted mortality rates, we can now calculate the ratio of these to observed mortality rates, i.e. $C_{t,s}$, and in turn we calculate X_t . As the QQ-plot of X_t in Figure 4 shows, it is clear that X_t is not normally distributed. In this case bootstrapping will retain the non-normal behaviour of the tails, which is of particular interest in capital determination and risk management in general.

Table 1: P-values of two-variable regression of X against age (x) and year (t)

| Model Type | Variable | ANOVA p-value |
|-----------------|----------|---------------|
| Continuous Case | Year | 0.1079 |
| | Age | 0.8350 |
| Discrete Case | Year | 0.9965 |
| | Age | 0.9999 |

⁸ It is notable that the strongest diagonal appears similar to that found by Richards (2008b: 288-289) and Cocevar (2007) for the UK and Italy, respectively, for the calendar years 1919 and 1920. This has its origin in unusual calendar year patterns in post-First World War births. It may be that Australia experienced a similar issue around the turn of the last century.



By fitting a two-variable regression of X_t against both age and year, we see from Table 1 that X_t is not significantly associated with age or time.⁹ Hence, we examine the impact of treating X_t simply as a random variable X . This implies different C_t paths for each age, as there will be a unique realisation of X for each age in a given year, whereas the X_t structure imposes the same outcome on all ages in a given year. The plots in Figure 5 and Figure 6 show the first 100 possible paths of 10,000

simulations performed and display fan-charts for C_t and $q_{65,t}$ ¹⁰, respectively.

The difference between the two approaches mentioned above, namely, X_p , that is, applying the same X_t to all ages in year t and X , that is, applying different X to different ages in any year, is revealed when we forecast values that progress over both age and time, such as cohort survival curves and associated annuity values, we will obtain narrower confidence intervals

⁹ This is to be expected, since the model has as one objective that residuals are pattern-less.

¹⁰ The central estimate comes from Tickle and Booth (2014) as described in Section 5 of this paper.

Figure 7: Histogram (LHS) of $a_{65[31]}$ (at 4% pa) and cohort survival curves (RHS) for Australian females (X)

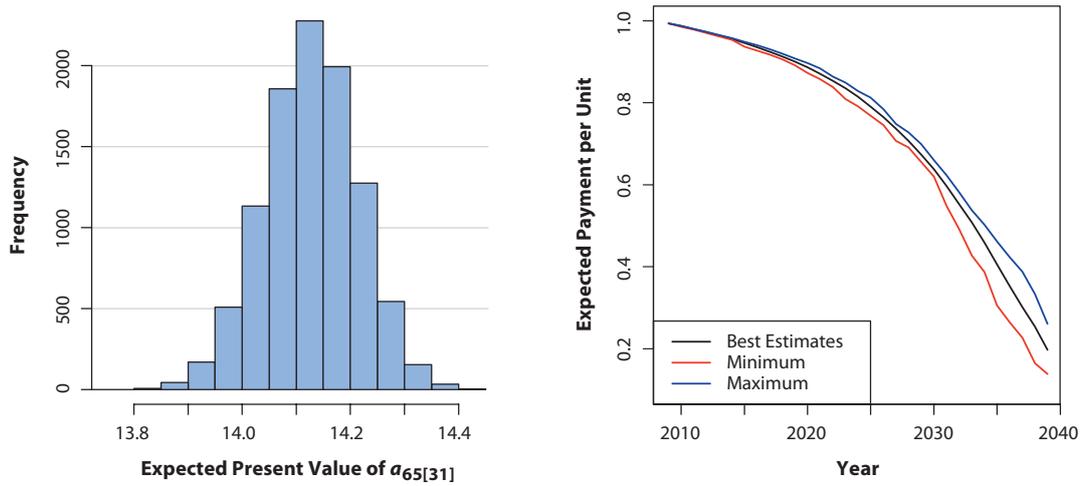


Figure 8: Histogram (LHS) of $a_{65[31]}$ (at 4% pa) and cohort survival curves (RHS) for Australian females (X_t)

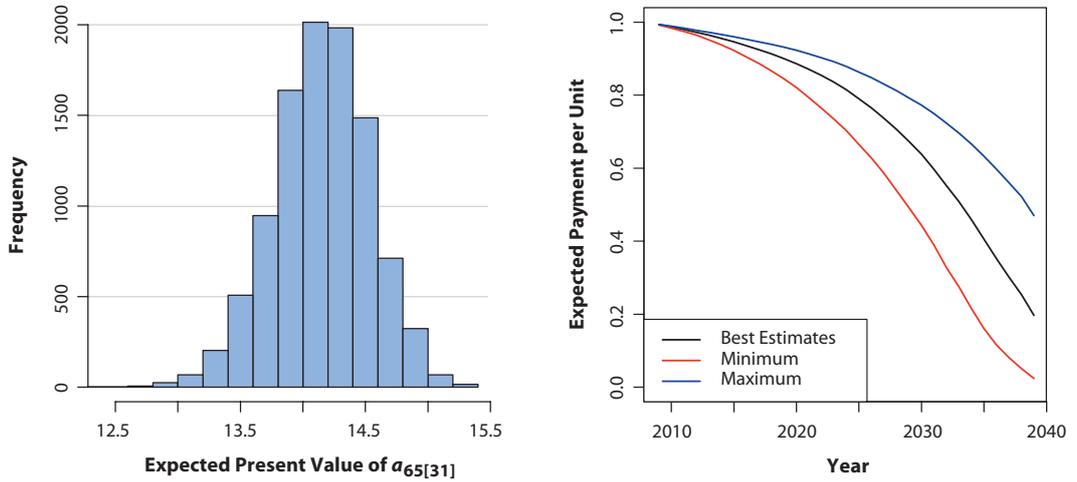
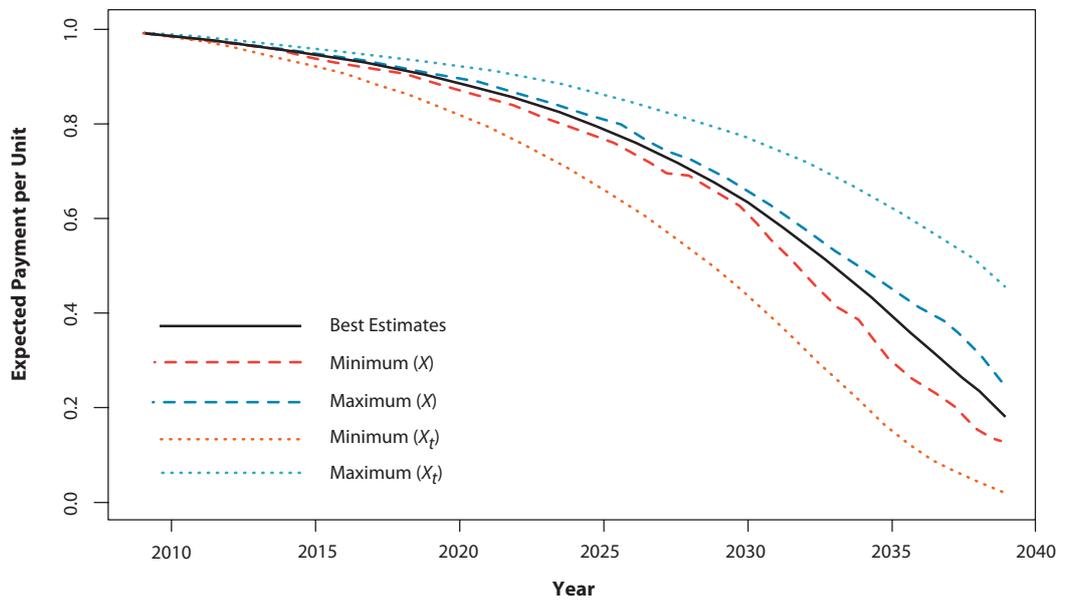


Figure 9: Paths of cohort survival curves for $a_{65[31]}$ for Australian females (two cases)



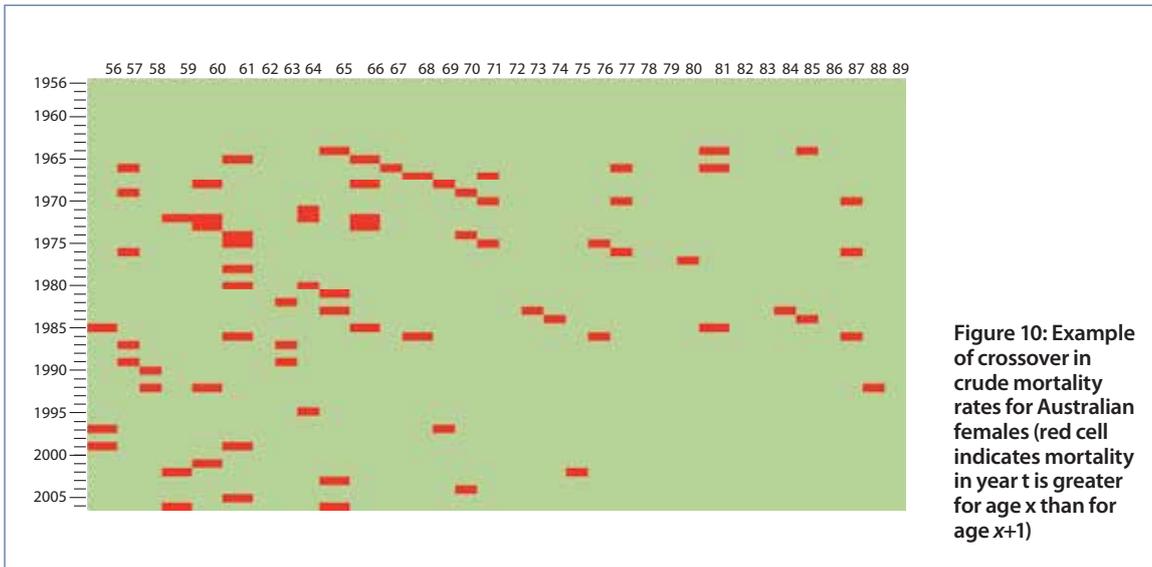


Figure 10: Example of crossover in crude mortality rates for Australian females (red cell indicates mortality in year t is greater for age x than for age $x+1$)

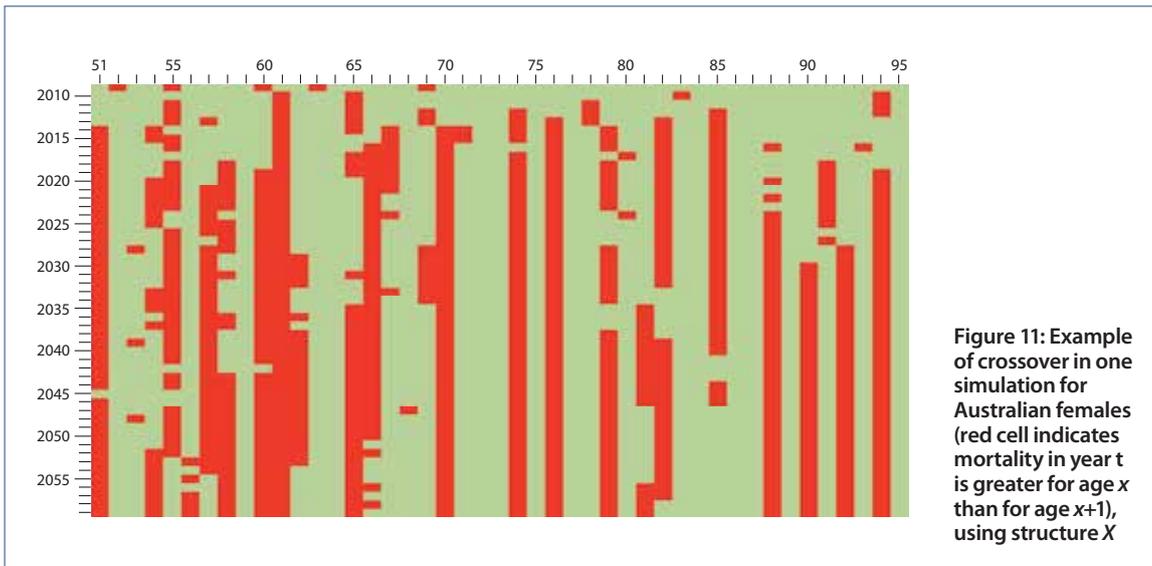


Figure 11: Example of crossover in one simulation for Australian females (red cell indicates mortality in year t is greater for age x than for age $x+1$), using structure X

when we use X than using X_t . Figures 7 and 8 provide histograms of the range of annuity values and the underlying cohort survival curves for the two cases. The two cases are overlaid in Figure 9 for direct comparison.

In addition to the differing width of the intervals, the “smoothness” of the path for the X_t structure compared with the “roughness” under the X structure is clearly apparent.

If we use X in the simulations of future variability, we are likely to violate overall coherence in the age structure of mortality, as we will observe sustained crossover between mortality rates for successive ages. Crossover here means that, in crude mortality rate observations for a given year, there may be mortality at age x that is greater than that of age $x+1$. This does occur in observations, see Figure 10, but this is not

observed on a sustained basis, which can be the case in simulations (cf. Figure 11).

It is worth pointing out that both using X and using X_t are simplification of reality. We conjecture that there is a more complicated relationship between X and age; however, this is outside the scope of the current work. For the purpose of this work, given that confidence intervals are frequently considered to be too narrow (Tickle and Booth, 2014, p 14), given the broader sources of uncertainty in long-term forecasting and given that we propose this method for examining downside risk for bearers of longevity risk, we conclude that using X_t , as in the original model, is the preferable choice of the two for the purposes of this paper. We also note that it is analogous to the κ_t structure of the Lee-Carter model (Koller 2011).

5 COMPARISON WITH OTHER METHODS

In this section we first compare our approach with a recently published stochastic mortality forecast for Australia and then with current regulatory capital requirements in Australia for life insurers in respect of longevity risk.

Tickle and Booth (2014) evaluated and updated a forecast of mortality for Australian seniors using the Booth-Maindonald-Smith variant of Lee-Carter. A central forecast of mortality rates for males and females aged 50 to 95 along with 80% prediction intervals were generously made available to us and are the best estimate basis for our comparisons.

The Australian Prudential Regulation Authority (APRA) is responsible for the prudential regulation of much of the financial services industry in Australia, including life insurers. Life insurance regulatory capital requirements are described in a suite of Life Prudential Standards (LPSs) and the requirements for longevity risk are defined in LPS 115 Section 38 “The ‘longevity stress’, before adjustment for diversification, is a 20 per cent decrease in the best estimate mortality rate for each age from the reporting date for the remaining term of

the liabilities” (APRA 2013: 7). The intention is that a calculation on this basis results in “no more than a 0.5 per cent probability that the actual cost of claims will exceed the stressed estimate” (APRA 2013: 6).

We see in Figure 12 that the prediction intervals for a given age for our approach are very close to those produced by Tickle and Booth (2014). However the structure of the APRA approach to stressing mortality rates produces a very different pattern over time from that of the bootstrap approach. In itself this may not be a concern if the resulting liabilities are of the same order.

However Figure 13 and Table 2 demonstrate that this may not be the case.¹¹ While the APRA approach generates cohort life expectancies and annuity values 4.4% and 3.1% higher than the central estimate respectively, the chosen bootstrap approach produces results 9.9% and 6.2% higher. As expected, the other bootstrap approach produces deviations considerably lower than the chosen structure.

These results provide a valuable basis for considering the adequacy of APRA’s goal of 99.5% sufficiency of capital.

¹¹ These calculations were not performed using Tickle and Booth’s forecast (2014), as they explicitly provided prediction intervals only, and not cohort life expectancy.

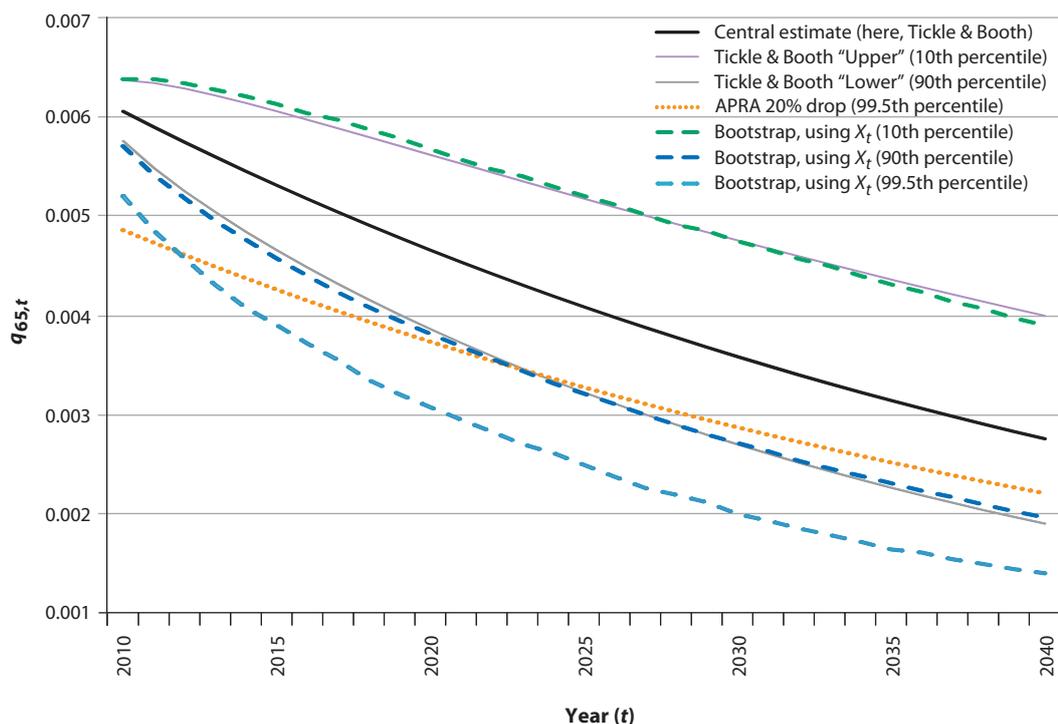


Figure 12: Forecast mortality rates for Australian females aged 65, central estimate and selected percentiles

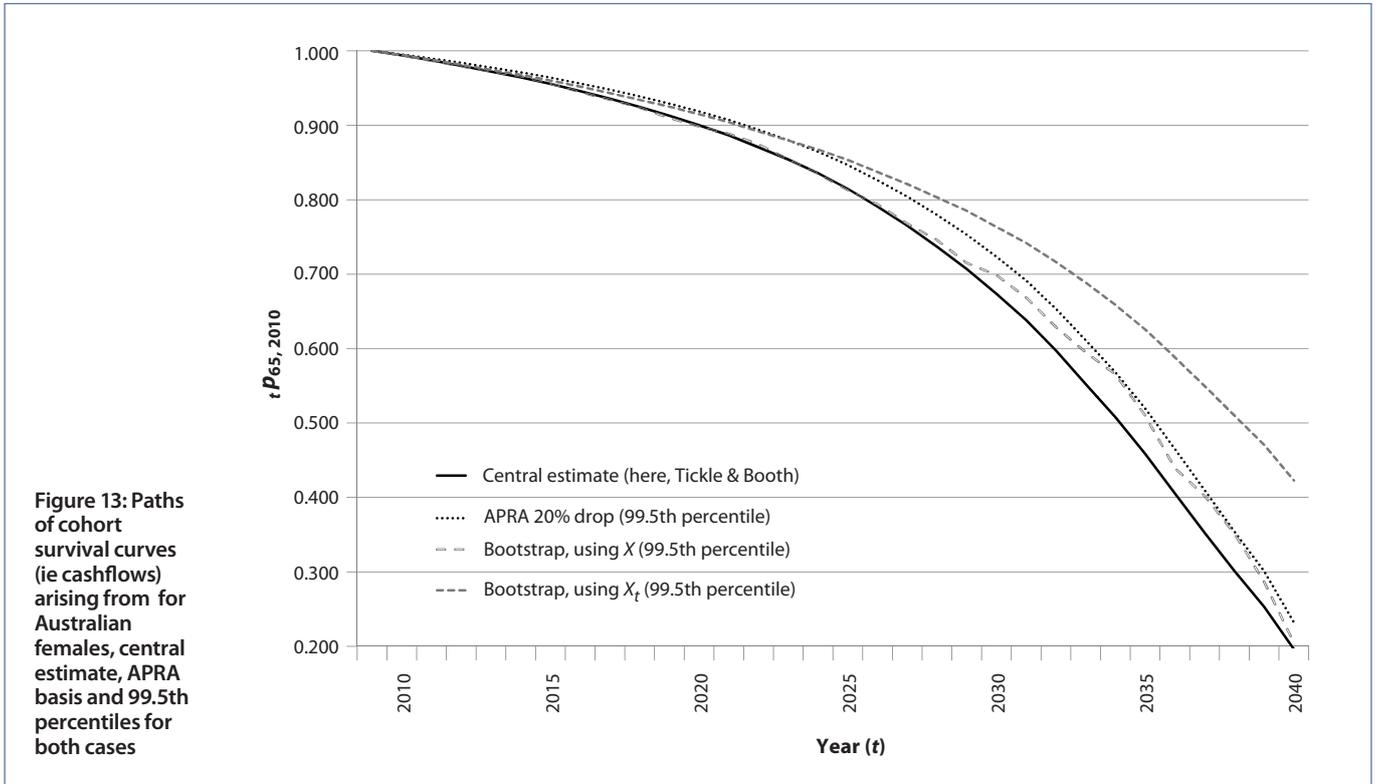


Table 2: Comparison of cohort life expectancy and annuity values (at 4% p.a.) for Australian Females aged 65 in 2010, central estimate and selected percentiles

| | $e_{65[31],2010}$ | % diff | $a_{65[31],2010}$ | % diff |
|--|-------------------|--------|-------------------|--------|
| Central estimate (here, Tickle & Booth) | 22.668 | | 14.166 | |
| APRA 20% drop (99.5th percentile) | 23.655 | 4.35% | 14.610 | 3.14% |
| Bootstrap, using X (10th percentile) | 22.287 | -1.68% | 14.019 | -1.03% |
| Bootstrap, using X (90th percentile) | 22.845 | 0.78% | 14.254 | 0.62% |
| Bootstrap, using X (99.5th percentile) | 23.102 | 1.91% | 14.325 | 1.12% |
| Bootstrap, using X_t (10th percentile) | 21.415 | -5.53% | 13.636 | -3.74% |
| Bootstrap, using X_t (90th percentile) | 23.817 | 5.07% | 14.645 | 3.39% |
| Bootstrap, using X_t (99.5th percentile) | 24.912 | 9.90% | 15.038 | 6.16% |

6 CONCLUSION

Extrapolative models for forecasting mortality are frequently stochastic by construction. Methods that blend extrapolation into a long-term expectation, such as the CMI method that has been applied in the United Kingdom, United States of America, Canada, Australia and China (SOA, 2014, Office of the Chief Actuary, 2014, Huang and Browne, 2014, CMI, 2009a, CMI, 2009b), and pure expectation methods, such as those used by some national statistics bodies (ABS, 2013, ONS, 2013), suffer from a major limitation in that they

are deterministic. They tend to provide a central or best estimate and additional “high” and “low” scenarios, which do not have any probability attached to them. Our method addresses this important limitation, allowing any deterministic forecast to become stochastic. This enhances the functionality of the forecast significantly, improves the communication of the range of possible outcomes and should benefit risk and capital management for both public and private entities.

The model attempts to capture systemic longevity risk. It aims to somewhat reduce model risk by decoupling the variation from the deterministic best

estimate. The case for this is further strengthened when we move to a non-parametric approach. When we have enough observations to justify the use of bootstrapping, one advantage is that we are not obliged to resort to transformations to impose pseudo-normality on a process that may not be normal or indeed to define a formal distribution for the process. This method thus captures the tails of the observed distribution of outcomes well, which is vital for risk management.

Describing potential future systemic variation in population mortality rates is always going to be a case of the “best available approximation of the truth” as eloquently put by Richards (2013). It is clear that the long-term future of population mortality is currently unknowable and may always remain so. By examining past variability we can set a benchmark for future potential variability, which the user may strengthen to allow for both “known unknowns”, such as the impact of future medical treatment breakthroughs, and “unknown unknowns”,¹² as they judge appropriate.

In this paper we have modified a simple stochastic model that can be used to attach variation to any best estimate by taking a non-parametric approach. We presented sample simulations of mortality rates and cash flows from an annuity product based on Australian female data. We compared this model with

a recently published stochastic mortality forecast and current regulatory capital requirements in Australia. Our method results in very similar prediction intervals to those of Tickle and Booth (2014) for age-specific mortality rates. We further inform the process of setting a longevity stress to achieve adequacy at an intended percentile, finding that the current approach to determining capital requirements may not be meeting this objective.

7 OUTLOOK

The bootstrap method discussed in Section 3.2 is the most basic of this family of techniques. It relies on the assumption of independence among residuals. Although the various tests we conducted did not suggest violation of this assumption, it is arguable that there still could be some pattern in the residual plots. More sophisticated bootstrap methods might be of help to mitigate such concerns. For example, the so-called “block-bootstrap” method (Liu & Braun 2010), in which a residual plot is first divided into a number of blocks in order to preserve the pattern in each block and then re-samples are taken from these blocks, looks promising. Clearly, this method is more time intensive since the

12 Donald Rumsfeld, US Department of Defense News Briefing, February 2002

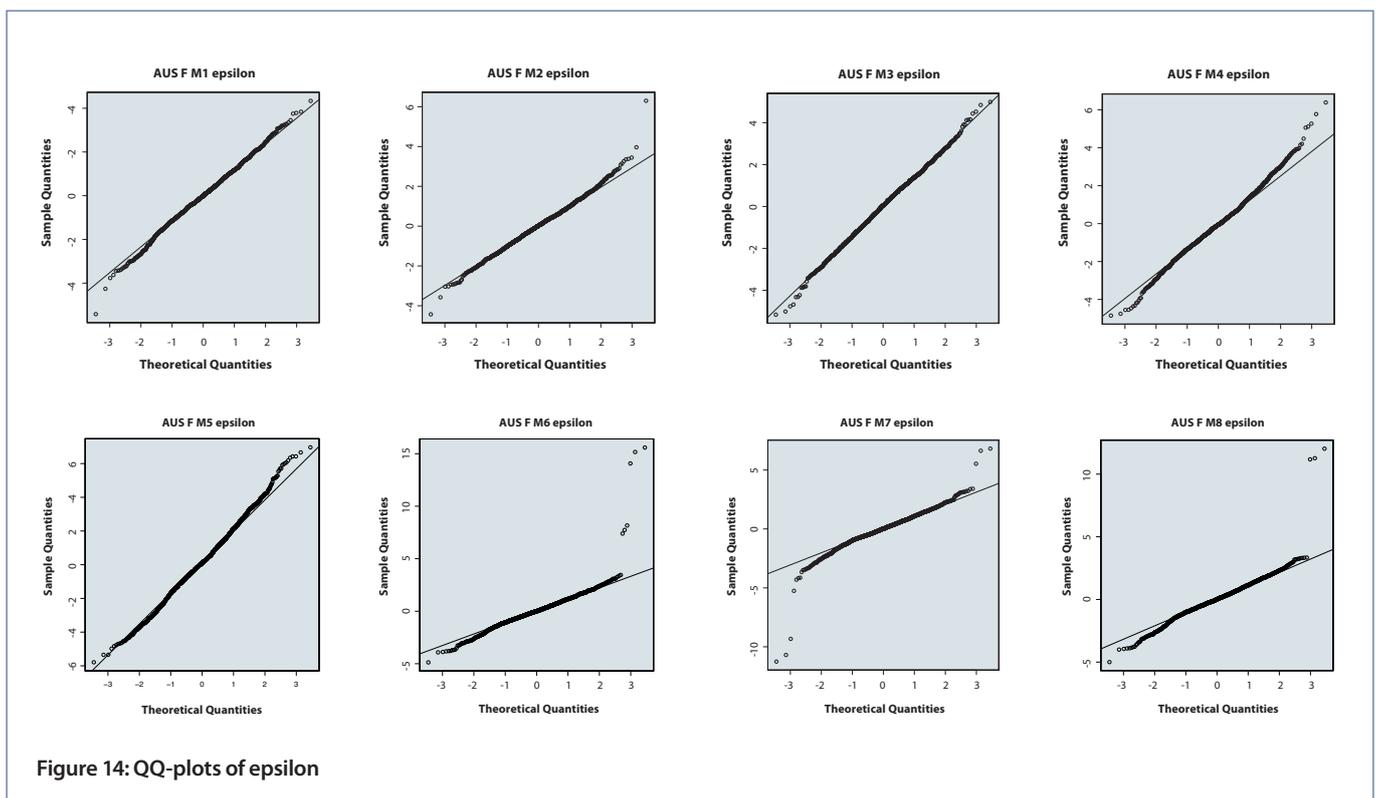


Figure 14: QQ-plots of epsilon

number, size and shape of blocks all require intensive investigation. This will be discussed in our follow-up publication. Lastly the relationship between X and age is worth further investigation.

APPENDIX: MODEL ASSESSMENT

In this section we briefly discuss choice of smoothing models. Here we follow the relevant components of the back-testing framework set out in Cairns et al. (2009) and Dowd (2010).¹³ Since model selection largely depends on the proposed usage of the model, we first outline where and how we use smoothing models in our current investigation. Recall that we are given a set of best estimates for future mortality rates and want to attach a variation measure to these best estimates. Thus, the question is how to find a reasonable description of mortality variation. In this case, we are talking about the variation of observed mortality with respect to its expected value, which is exactly where we need to choose a smoothing model. Once the model is chosen, the expected mortality can be calculated from the model and in turn variation is derived by comparison. In the following paragraphs we discuss some criteria used to support the ultimately subjective choice between various smoothing models.

Standardised residuals and BIC

First, it is desirable to have the model fit past data well. To do so, we inspected the QQ-plots and contour plots of standardised residuals to see if there is any pattern. Recall that all models in LifeMetrics assume that the resulting standardised residuals from each model are identical and independent normal random variables (Coughlan et al. 2007). Hence, it is desired to see almost-straight-line QQ-plots and pattern-less residual contour plots. We fitted M1–M8 to Australian female mortality data during the period from 1954 to 2008.¹⁴ And the resulting plots are produced below. The QQ-plots (Figure 14) indicate that M1, M2, M3 and M5 reasonably satisfy the normality assumption, while other models do not as they display some significant outliers.

The BIC value is listed in the title of the contour plots (Figure 15). M4 has the highest BIC, although its structure means it may not be directly comparable to the other models tested; M5 has the second highest BIC and the mean of the residuals is furthest from zero (Table 3); the other models' BICs are close together. Therefore, we will focus on the pattern displayed in

Table 3: Summary statistics for epsilon

| Model | Mean | Variance | Skewness |
|-------|-----------|----------|-----------|
| M1 | -0.000606 | 1.489723 | -0.087587 |
| M2 | 0.007536 | 1.088392 | 0.134849 |
| M3 | -0.003997 | 2.028962 | -0.085894 |
| M4 | -0.019290 | 2.078517 | 0.172425 |
| M5 | 0.166069 | 3.876925 | 0.139640 |
| M6 | 0.034808 | 1.842268 | 2.350169 |
| M7 | -0.005507 | 1.496240 | -1.015056 |
| M8 | 0.020308 | 1.582045 | 1.035231 |

these contour plots. Models M1, M4, and M5 (see Figure 15) do not incorporate a cohort effect and the unsatisfactory nature of this structure can be seen in the diagonal clusters of similar residuals. M6, M7 and M8, at first glance, look reasonably random, but closer inspection reveals distinct horizontal bands that suggest that there is a genuine random age effect that has not been sufficiently accounted for by these models.¹⁵ M2 and M3 look reasonably random, passing the test on a visual inspection and supported by the summary statistics.

Forecasting properties

Recall that our aim is to attach variation to central estimates. If the variation measure is reasonably accurate then we should be confident that the future realisation of mortality would fall into certain prediction intervals. To this end, we consider the accuracy of forecasts over different horizons against the realised outcomes for those horizons. Accuracy is reflected in the degree of consistency between the outcome and the prediction interval associated with each forecast (Dowd et al. 2010). Forecasts performed for M2 were unstable and prediction intervals appeared unreasonably wide, thus only results for M3 are shown here. We test two periods. We see the improvement in fit for M3 by comparing Figures 16 and 17. Although M3 systematically underestimates the mortality improvement in this particular case, we observe that the realised mortality rates fall into the 90% prediction interval. Thus, for the purpose of this paper, M3 was found to be most reasonable as a source for resampling X_t .

¹³ It is important to mention that for illustrative purposes, we retain the model structures used by the original authors for all time series involved.

¹⁴ To avoid edge effects, residuals from the first two years and the last two years were deleted. That is, only residuals from 1956 to 2006 are shown in graphs in this section.

¹⁵ It should be noted that M6–M8 are highly data-specific and there is no reason why we should expect they would work for our data without further adaptation.

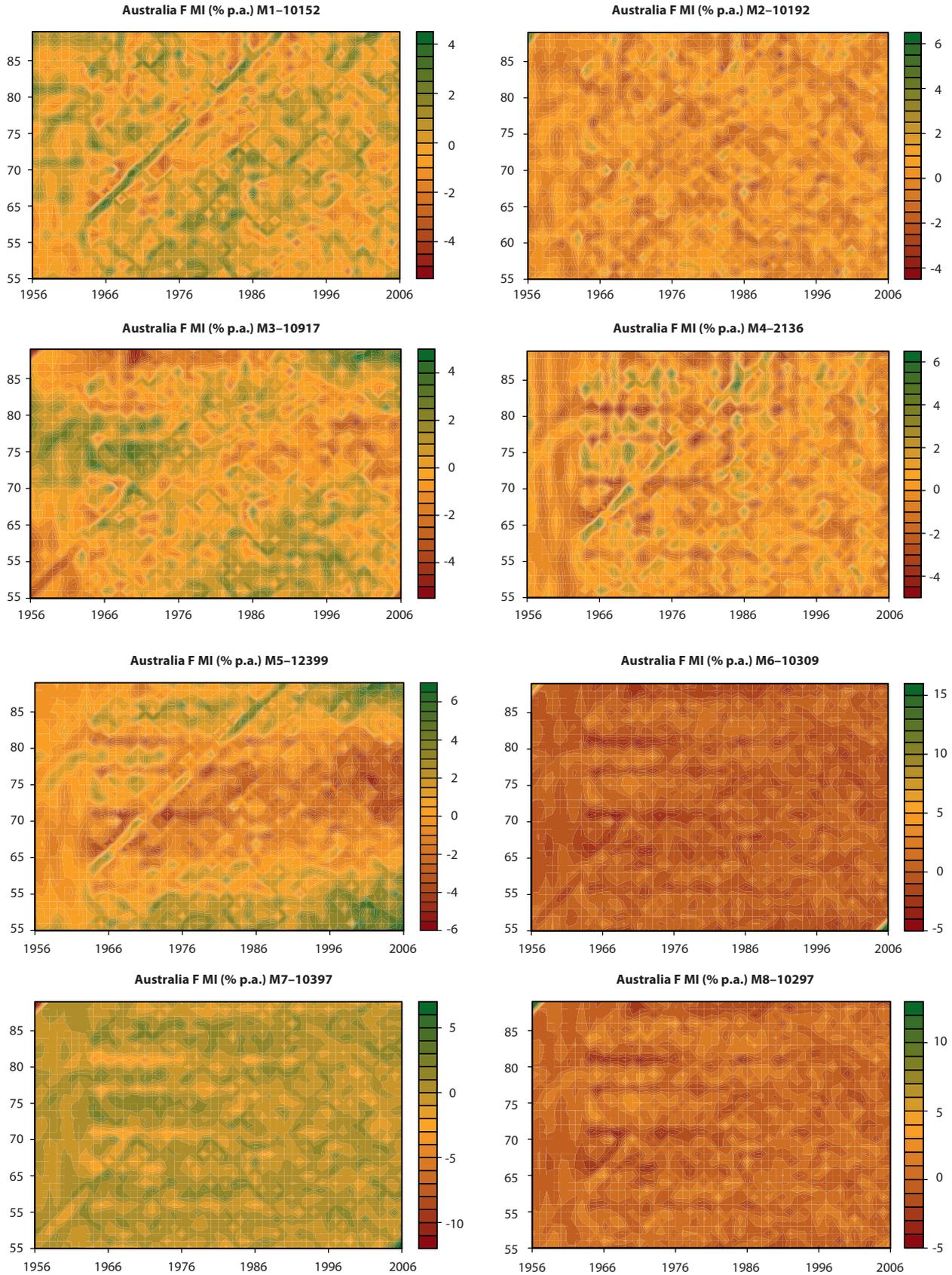
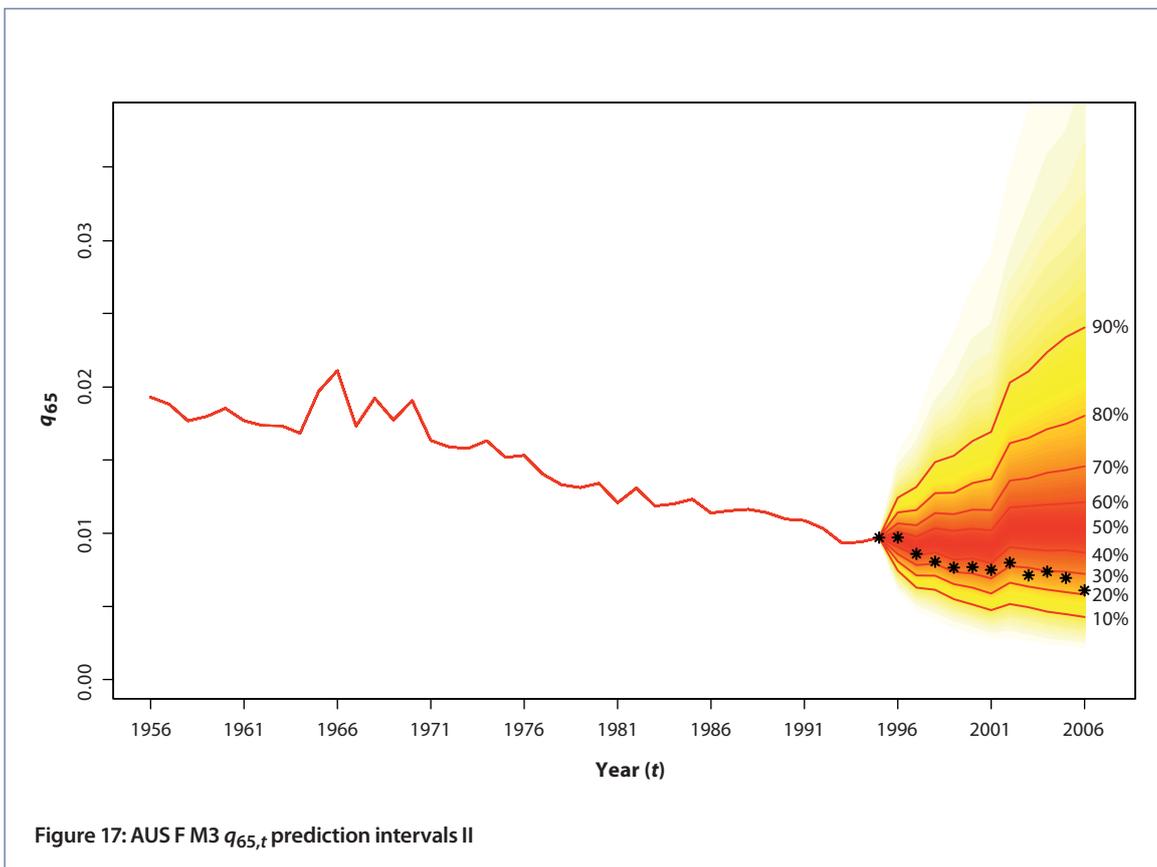
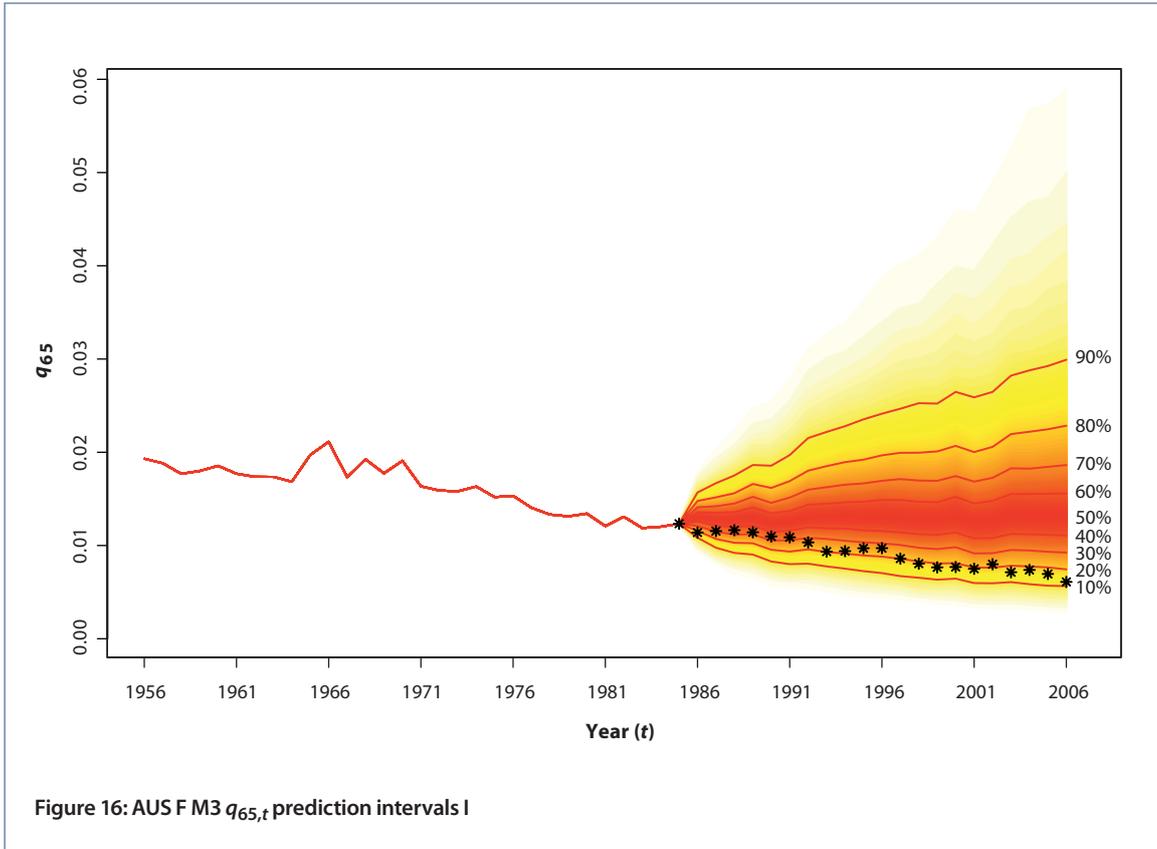


Figure 15: Residual Plots



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A survey of actuarial graduates' views on their education

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ABSTRACT

This paper presents the results of a survey of recent graduates of some Australian university actuarial programs. The survey aimed to shed light on graduates' views relating to their education since leaving university. The findings from our work can be used by those currently reviewing actuarial education programs in Australia. There is a strong view that the technical content of Part I courses is useful in the employment areas targeted by those courses, but there are concerns with the level of feedback provided to students. The Part II results indicated a much higher satisfaction with the content than the Part I courses in preparing students for employment. The Part III courses were not rated as highly as the Part I and II courses, and the teaching quality and feedback were particularly criticised, but they score well on relevance to employment. Well over 50% of graduates considered non-technical training as very important for their readiness for employment. While there is considerable support for provision of training in some non-technical skills, in most cases there is no clear majority opinion as to how this should be provided.

KEYWORDS

actuarial education, graduate survey

INTRODUCTION

This paper presents the results from a survey conducted with a group of recent graduates from the actuarial programs at the Australian National University and Macquarie University, and of members recently studying with the Institute of Actuaries of Australia (Actuaries Institute).

Those wishing to become a Fellow of the Actuaries Institute are required to complete a three part education process. The Institute does not specify what the specific purpose of each part is, so the comments in this paragraph represent the interpretation of the authors. Part I, which may be taken by sitting a series of Core Technical (CT) exams offered by the Institute and Faculty of Actuaries (UK), or by performance in equivalent subjects at an accredited university in Australia, consists of the fundamental mathematical, statistical, economic, financial and other material that actuaries are required to use across a variety of practice areas. Part II, which can only be completed by performance in subjects offered by an accredited Australian university, is designed to broaden the scope of the technical material in Part I by looking at the context in which actuarial work is performed. Part III, which is mostly provided by the Actuaries Institute through largely online courses, contains material similar to Part II in structure but typically through a more practice-area-specific lens.

The purpose of the survey was to ascertain the views of graduates on aspects of their university and post-university actuarial education. Given the employment of the authors at universities accredited to provide Part I and Part II education, the survey and this paper focus more on views relating to Part I and Part II, although some discussion on Part III is also provided.

The results of this survey are especially timely given the current ongoing and holistic review being undertaken into actuarial education by the International Actuarial Association (IAA), as well as concurrent reviews being conducted (focusing particularly on Part I or equivalent) by national associations such as the Society of Actuaries (US) and the Institute and Faculty of Actuaries (UK), which are likely to affect Australian actuarial education as well. The survey was initially motivated by the same reasons as the IAA review: to investigate whether actuarial education is fit for purpose in preparing the actuaries of today and the future.

The survey used was pilot-tested on a smaller sample in 2013, and the results of that survey were reported in Butt et al. (2014). The interested reader may refer to that paper for a full description of the motivation for this work and a summary of past research in this field. While the previous paper mostly reported on the results only,

this paper will provide comments and implications for education from the results of the survey.

Section 2 describes the survey used in this paper. Section 3 summarises the results of our survey. Section 4 concludes the paper.

1 SURVEY DESCRIPTION

Before any potential survey respondents were contacted, ethics approval was obtained from the relevant committees of all authors' institutions.

1.1 Sample selection

The Actuaries Institute selected members who had sat Institute-administered courses between 2009 and 2014.

The Alumni Offices at the Australian National University and Macquarie University selected all graduates from their respective actuarial programs (undergraduate and postgraduate) completing their degrees between 2009 and 2014 inclusive.

Each organisation emailed all the potential respondents they had identified, inviting them to complete the online survey. In order to increase response rates an incentive was offered, consisting of a \$200 voucher to 10 random respondents.

There is some overlap between the three groups invited to participate. This is discussed further in Section 2.1.

1.2 Survey implementation

The survey was implemented via the SurveyMonkey website. The emails to potential respondents inviting them to take part included the URL to the survey. Online surveys tend to produce lower error rates than paper-based surveys, since they can build in the logic to flag errors as they occur, allowing the respondent to fix them before submitting the survey. The survey incorporated branch logic, so that questions may be hidden if answers to earlier questions indicate they are not relevant.

Invitations to participate were emailed in early August 2014. The three organisations involved each individually selected a dispatch date to fit in with their other scheduled mailouts. This meant that the three organisations involved were not all sending their invitations on the same day. This is not an issue since the survey does not contain any time-sensitive questions. The Actuaries Institute and the Australian National University also sent one reminder email to potential respondents and the survey was closed to new responses in late August 2014.

1.3 Survey questions

For reasons of brevity, the full list of questions asked in the survey is not presented here, although interested

parties are welcome to contact the corresponding author, who will gladly provide them. This subsection provides a brief summary of the content of the survey. The survey was not materially different to that completed by the pilot respondents and described in Butt et al. (2014). It should also be noted that, apart from situations where only respondent subsets are being presented, the titles of figures and tables in Section 2 represent the exact wording of the questions asked of the survey respondents.

The survey commenced with a range of demographic questions, which may help detect any strong differences between distinct sub-groups. This includes such information as age, gender, field and country of employment, length of employment, English-language background, membership of actuarial bodies and detailed data concerning progress through the professional exams (Australian or elsewhere).

It then moved on to the major issues we were investigating. For each of Parts I, II and III of the professional exams that respondents had attempted, they were asked to rate the following factors.

- perceived usefulness of material in their current employment;
- strengths or weaknesses of factors such as syllabus and teaching quality; and
- the size of the syllabus.

The survey then moved onto non-technical skills, as described in the Institute's Capability Framework and other frameworks produced by other actuarial associations, seeking information about written and oral communication skills, leadership, problem-solving, professionalism, ethics, strategy and teamwork. For each of these areas, respondents were asked for their perceptions on the importance of these skills, how well these skills were developed over Parts I, II and III and elsewhere, and where respondents believe these skills should best be developed.

Throughout these questions, numerous options allowed respondents to include additional open-ended responses to clarify the reasons for their ratings. These typically took the form of "Please comment on your answer to this question". Analysis of the responses to the open-ended questions began with emergent coding techniques to provide patterns of interpretive significance leading to the development of themes. This allowed patterns to be identified and meanings defined within those patterns (Charmaz 2006), which led to the construction of improved understanding of the data (Patton 2014; Rossman & Rallis 2003). This coding and analysis was undertaken by the author who is not a member of the profession, in order to provide an unbiased view in the coding process.

2 SURVEY RESULTS

This section concentrates on analysing the responses to the categorical questions asked in the survey, along with summaries of the open-ended responses where appropriate. In addition, sample open-ended responses that represent the key themes are presented. Categorical responses have been analysed for any relationship with demographic factors using ordinal logistic regression (Agresti 2012). While these results have not been formally reported here for reasons of brevity, anyone who is interested in these results is welcome to contact the corresponding author, who will gladly provide them. In almost all cases the demographic factors had no impact on responses, except for the examples that will be discussed in this section.

2.1 Response summary

The survey was open for completion from 1 August to 23 August 2014.

The invitation to complete the survey was sent to:

- 1052 members of the Actuaries Institute who had sat Institute-administered courses between 2009 and 2014 inclusive.
- 502 alumni of Australian National University who graduated with actuarial degrees (undergraduate and postgraduate) between 2009 and 2014 inclusive.
- 695 alumni of Macquarie University who graduated with actuarial degrees (undergraduate and postgraduate) between 2009 and 2014 inclusive.

There is some overlap between these lists. We are unable to quantify the amount of overlap since privacy requirements do not allow the three institutions to release their distribution lists to us or to each other.

While 287 people responded, 22 completed only the initial demographic questions, and did not respond to any of the issues we were researching. The analysis is based on the 265 respondents who provided usable responses beyond the initial demographic data.

Assuming no overlap between the three sets of invitees, these 265 responses represent a minimum response rate of 12%, the true response rate being higher due to the unknown amount of overlap. Unfortunately the true response rate is quite sensitive to the overlap. If only 50% of the graduates on the mailing lists of the universities were also on the Actuaries Institute list, the response rate would be 16%. For comparison, De Lange et al. (2006) report on a similar survey of accounting graduates from two Australian universities, obtaining a response rate of 26%.

While a very small number of the 265 respondents

omitted some of the demographic questions, of those who responded:

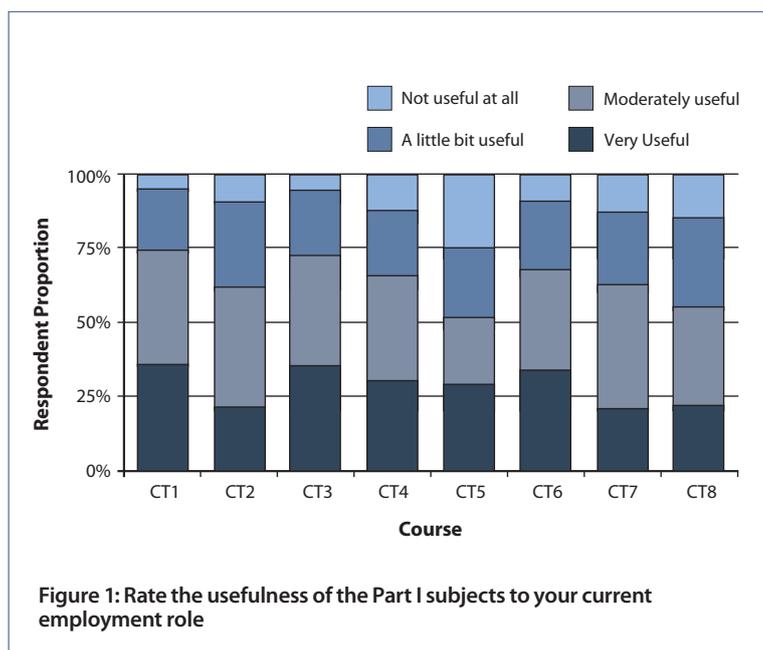
- 45% were still studying some sort of actuarial exam in 2014.
- A wide variety of employment areas were represented, the most common being general insurance (24%) and life insurance (23%); 10% are full-time students.
- 71% are located in Australia, with the most common overseas locations being Malaysia (8%), Singapore (5%) and China (4%).
- 61% identified as male and 39% as female.

The demographics of the survey respondents are remarkably consistent with the demographics of the membership of the Actuaries Institute (Actuaries Institute, 2015). More detailed demographic data of the survey respondents is provided in the Appendix.

2.2 Usefulness of individual Part I subjects

Figures 1 and 2 present the results of questions focused on Part I of the actuarial education program, the Core Technical (CT) subjects. 90% of respondents undertook the bulk of their Part I study through an Australian university. The titles of the CT subjects are as follows:

- CT1 – Financial Mathematics
- CT2 – Finance and Financial Reporting
- CT3 – Probability and Mathematical Statistics
- CT4 – Models
- CT5 – Contingencies
- CT6 – Statistical Methods
- CT7 – Business Economics
- CT8 – Financial Economics



Further information, including syllabi, can be found at the UK Institute and Faculty of Actuaries website at <http://www.actuaries.org.uk/studying/prepare-your-exams/syllabus-and-changes-syllabus>.

Before 2010, CT7 was named “Economics”, the change in name indicating a slight change in emphasis. The change in content was sufficiently small that we did not attempt to collect data as to which version each respondent attempted.

Figure 1 presents responses to the question “Rate the usefulness of the Part I subjects to your current employment role”. What is immediately apparent is the broad usefulness of all Part I subjects, with all subjects having a least 50% of respondents giving the subject at least a “Moderately useful” rating. In any case the “lower” ratings should not be read as an opinion that a particular subject should be removed from the syllabus as a respondent may still regard a subject as useful for the overall syllabus even though it is not useful in their particular area of work. Hence it is more useful to consider the results by employment area.

While more than a quarter of respondents rated each subject as less than “Moderately useful”, the low ratings are concentrated in two particular “employment areas” that fall outside the traditional employment areas: full-time students and the catchall “other (please specify)” category.

Given the wording of the question, we would consider the answers provided by those who still consider themselves to be full-time students to be somewhat less meaningful than the answers of those in employment.

For respondents who chose the employment area of “other (please specify)”, the job titles given are sometimes difficult to interpret, but they do include a range of work areas clearly outside traditional actuarial work, such as energy/utilities, statistician/data analytics/market research, telecommunications, law, auditing, software engineer and housewife. Given the bulk of the Part I material is aimed at more traditional actuarial work, it is not surprising that respondents from the above occupations rate the usefulness of the Part I material as low.

Whilst no significant differences were detected between Australian and overseas respondents, those who had done little study in English prior to commencing their Part I study tended to rate the usefulness of Part I subjects lower than other respondents. Another factor that caused lower ratings was a longer period of work experience, which is obviously highly correlated with the time since Part I was completed. It is unsurprising that Part I is perceived to be less useful the longer it has been since completion.

Another major determinant of whether a

respondent regards a particular subject as useful is their area of employment.

CT1 is regarded as useful across all employment areas, but is particularly favoured by those in investment banking, risk management and superannuation.

CT2, CT7 and CT8 are regarded as particularly useful by those in investment banking and financial consulting.

CT3 and CT6 are regarded as particularly useful by those working in general insurance.

CT4 is regarded as particularly useful by those working in life insurance, superannuation, and other financial consulting.

CT5 is regarded as particularly useful only by those working in life insurance.

However, to qualify the above comments, it does have to be noted that the number of respondents in many employment areas is too small for reliable statistical conclusions. The other way to approach this analysis is to identify the target employment areas for each Part I subject and determine how respondents from those areas rated that subject. (We have not identified the target employment areas for a subject by choosing the areas that gave the highest ratings for that subject, since that would introduce circularity in the argument. The identification of target employment areas has to be carried out independently of the data collected, and so was carried out by one of the authors who was not closely involved in analysing this section of the data.)

This process identified four Part I subjects with clearly targeted employment areas, where the number of respondents from those areas was sufficient to have confidence in the robustness of the results. The subjects and employment areas are as follows.

CT1: Financial Planning, Investment Banking, Retail Banking, Other Financial Consulting

CT5: Life insurance (consulting), Life insurance (internal), Superannuation (consulting), Superannuation (internal)

CT6: General insurance (consulting), General insurance (internal)

CT8: Investment Banking, Other financial consulting

Figure 2 shows how respondents in the target employment areas rate the usefulness of these four Part I subjects. These results are far more positive than those in Figure 1. Different Part I subjects were designed to cover material relevant to different practice areas. By and large, respondents' views are that the Part I subjects that aim to cover material relevant to their practice area are perceived to make a reasonable attempt at that task.

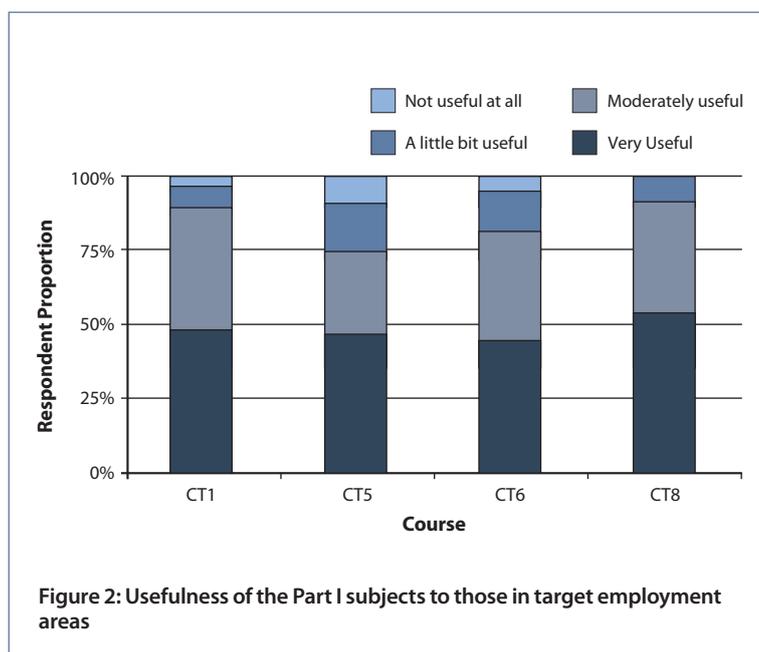


Figure 2: Usefulness of the Part I subjects to those in target employment areas

However, what the results of this section do reveal is the challenges facing those making decisions on syllabus content. Our results reveal no broad areas where current syllabus content can obviously be cut, but there are concerns from those working in non-traditional areas about the usefulness of the Part I syllabus. This is reflected in the updated IAA Syllabus (2015), which includes significant new material on Data & Systems, without any significant removal of content. Finding a balance between catering to traditional actuarial work, while meeting the needs of an ever-growing non-traditional workforce (see Actuaries Institute, 2015), will be an ongoing challenge.

2.3 Strengths and weaknesses of Part I

Figure 3 presents overall thoughts of respondents on the strengths and weaknesses of Part I of the actuarial education program. In this and future figures the following list identifies the categories within which these strengths and weaknesses are measured:

SC – Syllabus content (i.e. the relevance of the actual content taught)

SS – Syllabus structure (i.e. the order in which the subjects and topics were taken)

TQ – Teaching quality

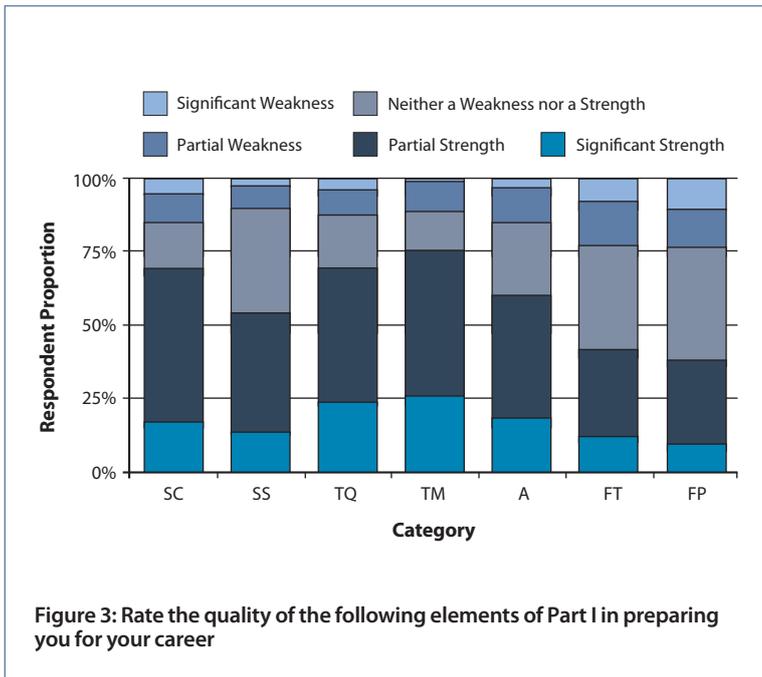
TM – Teaching materials (notes, online learning systems, etc.)

A – Assessment

FT – Feedback from teachers on progress

FP – Feedback from peers on progress

Most responses are favourable, with less than 25% of responses in all categories recording partial or



significant weaknesses. Clearly the weakest results are for feedback, a result which is probably of little surprise to academics, who are used to being asked to teach an increasing number of students in each class and an increasing number of classes, although the “Significant Weakness” responses largely come from those who took the Part I exams by distance through the United Kingdom.

Again, those who had done little study in English prior to commencing their Part I study tended to rate Part I as being weaker compared to other respondents. It is possible that this result represents a cultural difference in the way of responding to the survey (Lee et al. 2002) rather than an actual difference in opinion, although the survey responses cannot identify this.

It is also worth noting that whether a student had

completed future parts of actuarial education had little impact on the responses to this question.

Figure 4 presents a word cloud for the codes allocated to the open-ended responses for the questions regarding the usefulness and quality of Part I. Word clouds provide a snapshot of the themes coming out of a series of textual responses. The larger the “theme” the more frequently it appeared in respondent answers. One clear factor we noted is that respondents who had negative views of actuarial education were far more likely to give an open-ended response than those who had a positive view.

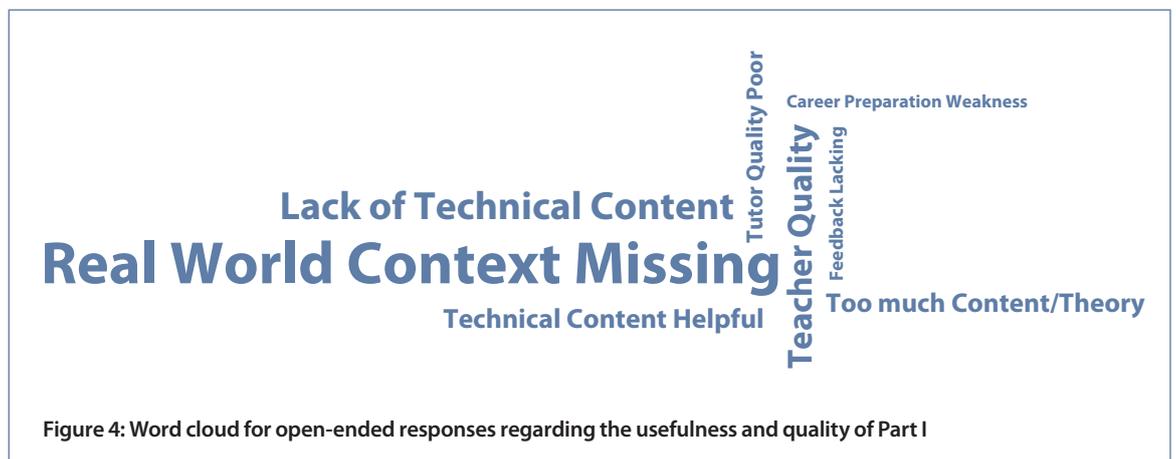
The clear, dominating theme here is the lack of context in Part I material. One response captures both this and the second theme well:

“Weakness lies in the lack of quantitative technical content for the banking/risk management/data analytics practice areas, and the lack of emphasis on practical actuarial softwares/computer coding prevelant [sic] in the industry.”

This comment captures the concern about the applicability of Part I material as well as the tension about what technical material should be taught, given the wide variety of industries actuarial graduates now work in.

2.4 Strengths and weaknesses of Part II

Figure 5 shows that in general Part II is considered to be stronger than Part I in preparing respondents for their career. The exceptions are Teaching Materials, which fares a little worse, and Assessment, which is largely unchanged compared with the Part I results. Feedback from peers is slightly improved compared with Part I, but still rates poorly.



Interestingly, the most prevalent theme regarding the quality of Part II from the open-ended response word cloud in Figure 6 is a lack of feedback. A response that captures this, and the difficulty in providing feedback in Part II, says:

“Feedback loops on progress are the recurring theme. It is challenging to give regular feedback in a more practical course which requires detailed discussion.”

We will discuss the other themes in more detail in Section 2.8.

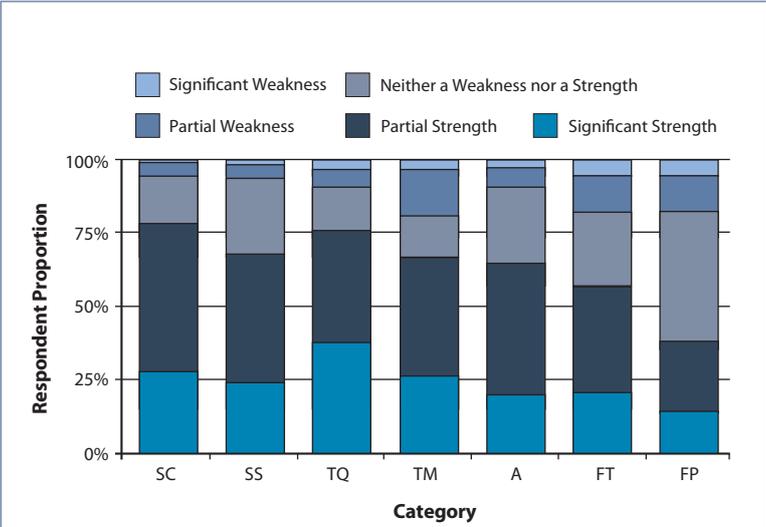


Figure 5: Rate the quality of the following elements of Part II in preparing you for your career

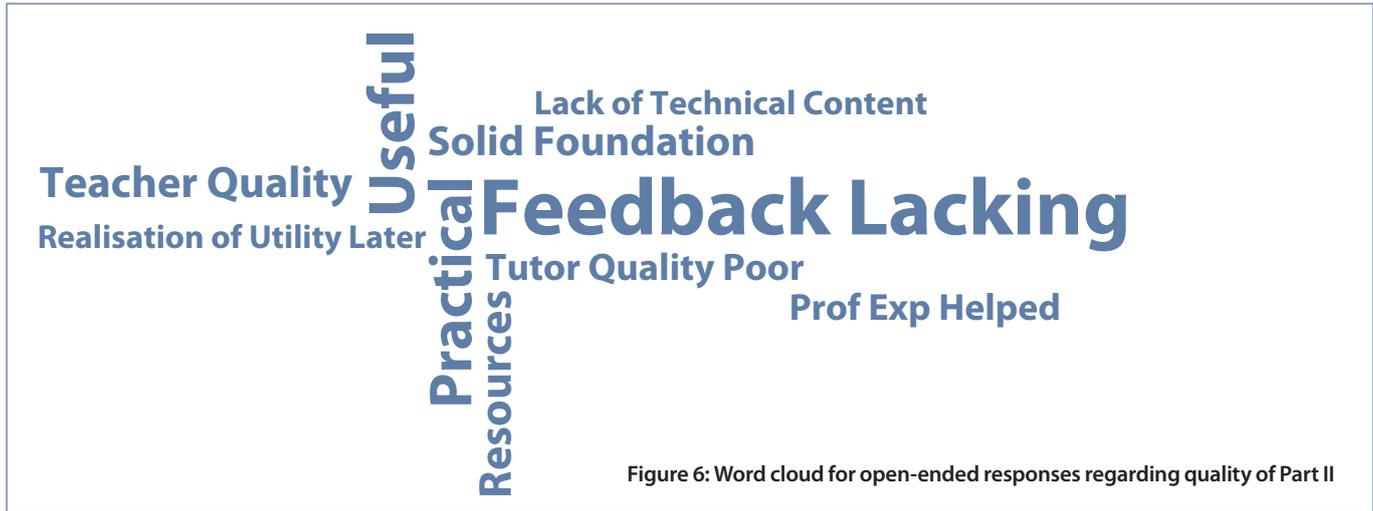


Figure 6: Word cloud for open-ended responses regarding quality of Part II

2.5 Strengths and weaknesses of Part III

Figure 7 presents the results of a question focused on Part III of the actuarial education program. There is a severe downturn in respondents' perceptions of the quality of the education they have received in Part III compared to Parts I and II.

Respondents are generally happy with the Syllabus Content delivered in Part III, with more than 70% rating Syllabus Content at a “Partial Strength” or higher level, and more than 50% rating Syllabus Structure at these levels. These results are broadly comparable to Parts I and II. However, the remaining elements all have less than 50% of respondents rating them at a “Partial Strength” or higher level, significantly below the level of Parts I and II, with Feedback from Teachers scoring particularly poorly.

Since many respondents are still progressing through the exams, or gave up part way through the exams, the number of respondents declines for the

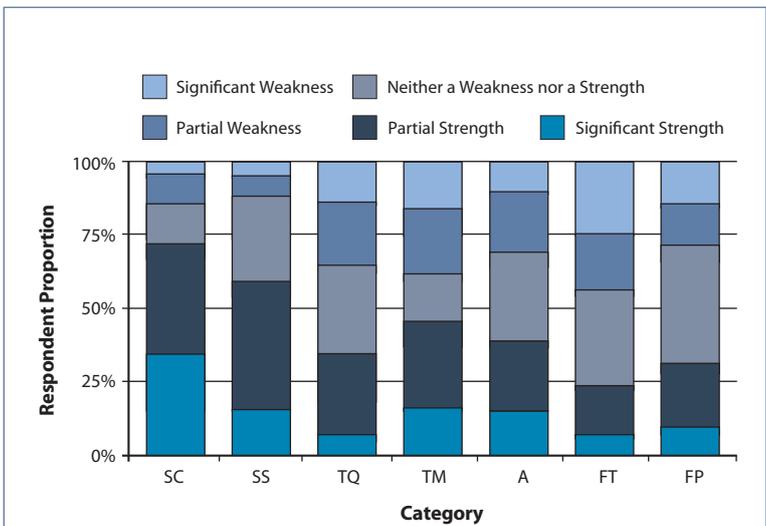


Figure 7: Rate the quality of the following elements of Part III in preparing you for your career

latter parts. The number of respondents fell in the range 246 to 258 for Part I; 181 to 183 for Part II; and 116 to 117 for Part III. The variability within each part is due to some respondents not responding for all categories or all subjects within that part.

There is always a trade-off in survey design. Asking more detailed questions theoretically allows more refined analysis, but longer surveys usually produce lower response rates, reducing the reliability of the results. Because of this, data already available from other sources was not collected. Respondents in this

survey were asked to rate their Part III experience in total, rather than individually rating each Part III subject they attempted, because the Part III quality control process at the Actuaries Institute already includes surveys at the individual subject level.

However, our survey did ask which Part III subjects the respondents had attempted, so we can investigate whether the perception of the overall usefulness of Part III varies with the subjects attempted. We were unable to find any material differences between results when split by subject(s) taken, except where the number of responses was sufficiently small that the results are not robust.

The open-ended responses tended to focus on the specific Part III subjects taken by the respondent, and so a word cloud is not presented here.

2.6 Other aspects of Parts I, II and III

Figure 8 presents the results of a question on respondents' perspectives on the amount of syllabus content across the three parts.

Figure 8 reveals that respondents believe that the amount of content taught in the three parts is appropriate. In fact, for all three parts more than 50% of respondents answered that the amount of syllabus content was "About right", although respondents were more likely to perceive an overburdening amount of syllabus content in Part III than the other parts.

These results are inconsistent with discussions heard by the authors at many actuarial education conferences, of an overabundance of content to teach in Part I and Part II. Perhaps this anecdotal evidence is more a function of academics wishing to have space to teach additional practical material not in the syllabi rather than any significant overburdening of content in current courses taught by universities.

To the authors, this is one of the most surprising results of the survey. When the smaller pilot survey produced a very similar result, we wondered whether our choice of trial respondents had been biased towards the more able students who were better able to cope with the workload. While this survey has somewhat removed that potential bias, it is still a survey of graduates and Institute members, so it does not capture students who abandoned an actuarial degree owing to not coping with the workload. That is, the survey may be selecting only those people who have coped with the amount of material in the exams. If there is a selection effect here, it would be reasonable that the effect would be evident if we compare respondents based on how far through the exams they have progressed.

Figure 9 shows respondents views on the amount of material in Part I, with respondents subdivided by their progression through the exams. The column labels are as follows:

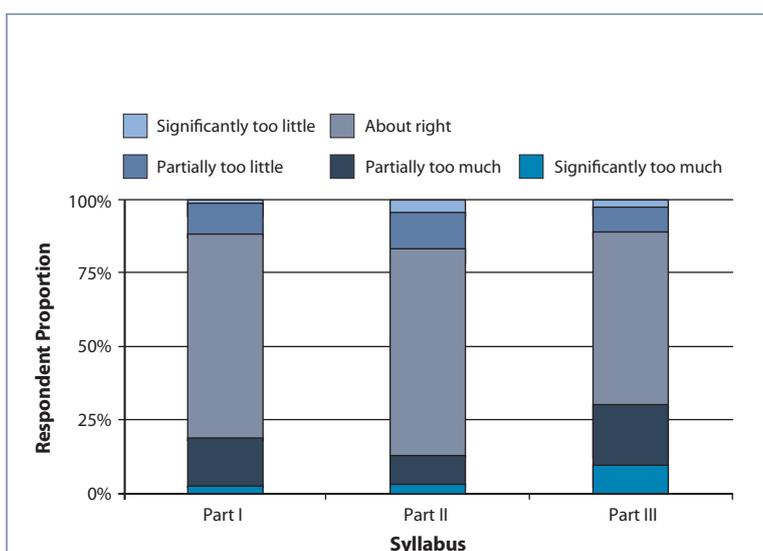


Figure 8: Comment on the amount of syllabus content taught in Parts I, II and III

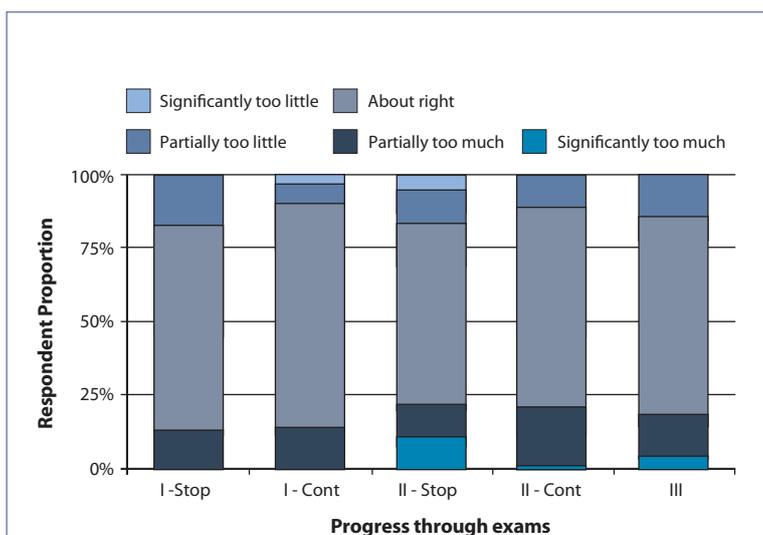


Figure 9: Perception of amount of Part I content subdivided by progress through the exams

- I – Stop: Completed some or all of the Part I subjects/exemptions (not intending to attempt further actuarial study)
- I – Cont: Completed some or all of the Part I subjects/exemptions (intending to attempt further actuarial study)
- II – Stop: Completed Part II (not intending to attempt further actuarial study)
- II – Cont: Completed Part II (intending to attempt further actuarial study)
- III: Completed Part III

There are no material differences visible here. Comparing the first two columns, those who have discontinued study are slightly less likely to say there is too little material compared to those who are continuing, but the proportions who say there is too much material match almost perfectly. Further, the difference in the “too little” category does not carry through to the remaining columns. This suggests we are not dealing with a selection effect.

Figure 10 shows the results of questions asking respondents who discontinued actuarial study to rate various reasons for their decision.

The columns are ordered by the strength of effect. The column labels are:

- Rel: Not relevant and/or necessary to my current occupation
- Int: Lack of interest
- Time: Takes too much time
- Diff: Too difficult
- NFS: Employer will Not provide Financial Support (study and/or membership fees)
- Loc: Current location of residence/employment
- NSL: Employer will Not provide Study Leave support

Clearly the major reasons for discontinuing are lack of relevance and lack of interest. Examination of the raw data shows those selecting these options tend to be those working outside the traditional actuarial roles, and there is considerable correlation between these two reasons, with respondents finding material less interesting if it is not relevant to their current occupation.

The time required to complete the exams and their difficulty are less important, but still significant reasons. That is, while most of the respondents who discontinued study believe the amount of material in the courses is about right, many did still discontinue due to the exams taking too much time. This suggests respondents are giving well-considered responses and are able to separate the issue of what should be in the exam from the issue of how much material they personally can fit into their available time.

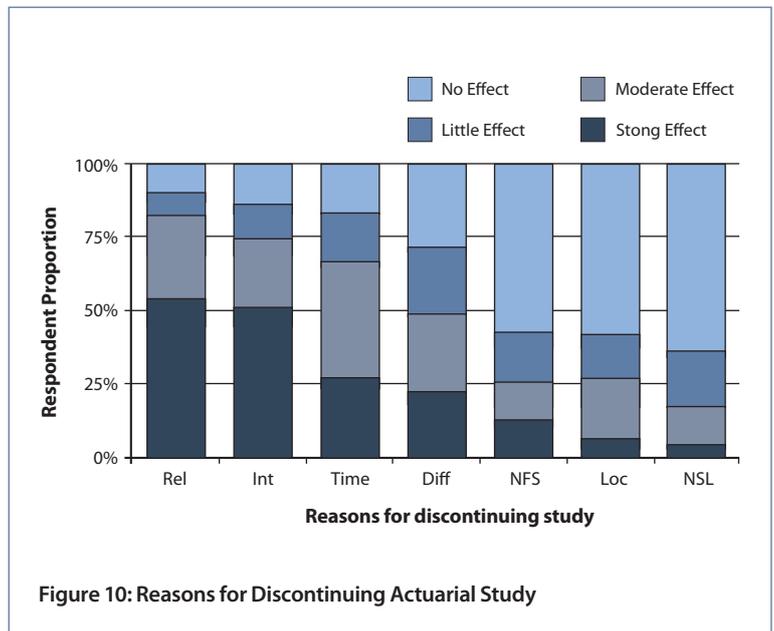


Figure 10: Reasons for Discontinuing Actuarial Study

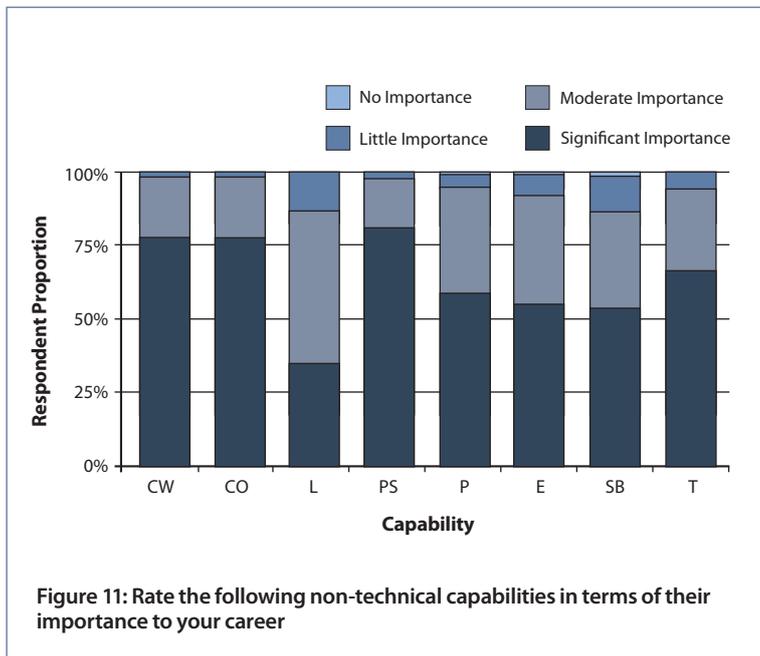
2.7 Non-technical capabilities

The remaining questions focused on non-technical capabilities, their importance to the careers of the respondents and the effectiveness and whether these capabilities should appear in the education structure. The non-technical capabilities were drawn and simplified from the Actuaries Institute Capabilities Framework. In the following figures, the column labels are:

- CW – Communication (written) to a variety of stakeholders
- CO – Communication (oral) to a variety of stakeholders
- L – Leadership of people to a common goal
- PS – Problem solving to provide practical solutions
- P – Professionalism
- E – Ethics
- SB – Strategic foresight to anticipate business trends
- T – Working in teams and managing relationships

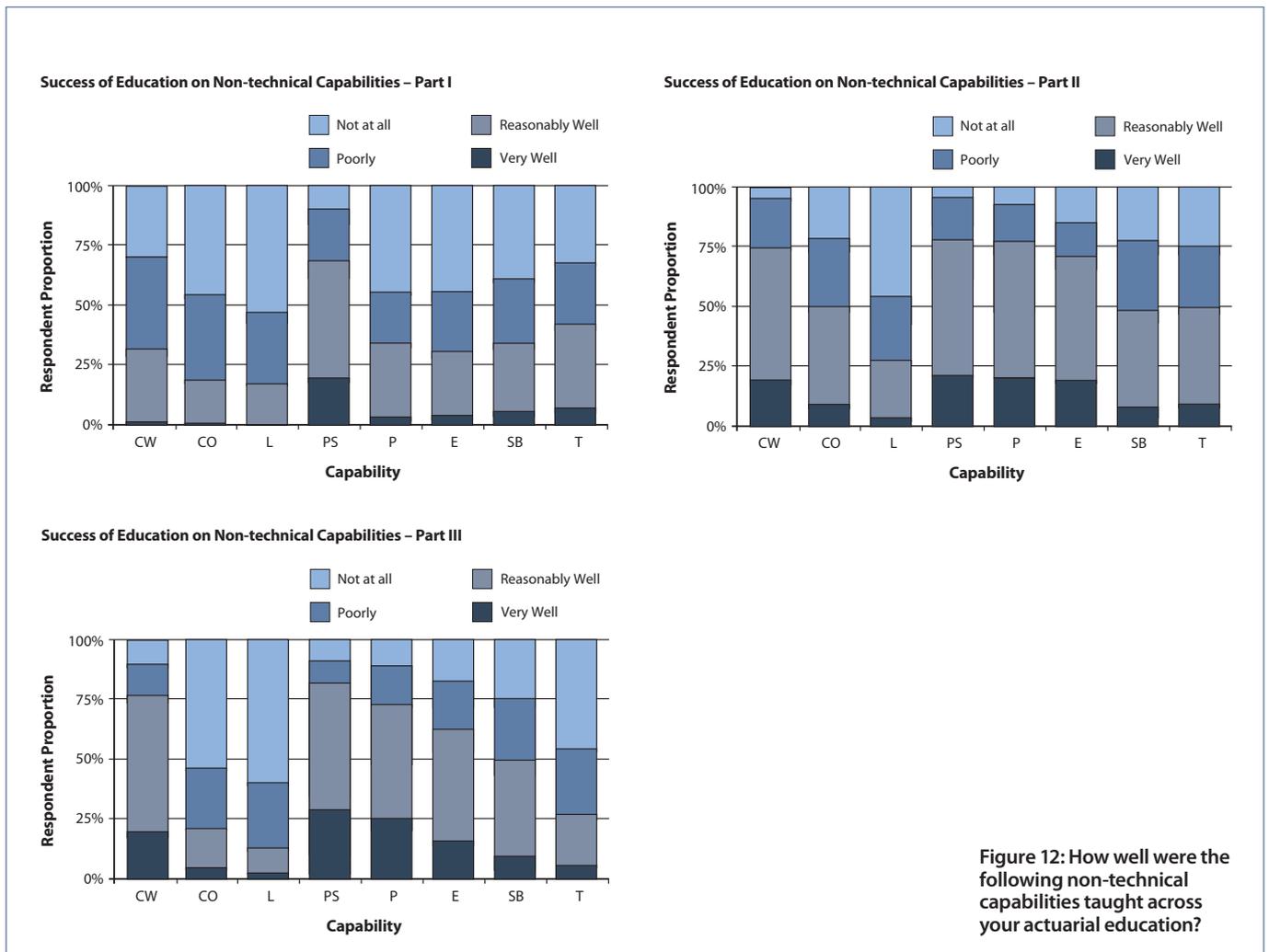
Figure 11 shows responses to the following question:

“Actuarial education literature and the Institute’s Capability Framework suggest actuaries require a number of ‘non-technical’ skills and capabilities to be applied in conjunction with their technical abilities. Rate the following non-technical skills and capabilities in terms of their importance to your career (in this context ‘career’ means both your current employment role and your future desired career path).”



The results from Figure 11 indicate that respondents overwhelmingly attach a significant level of importance to all the non-technical capabilities described. More than 75% of respondents rate communication and problem-solving skills as of significant importance. More than 50% of the respondents rate professional, ethics, strategic foresight and teamwork as of significant importance. While leadership seems to stand out as having much weaker results, with less than 50% of the respondents rating it as of significant importance, more than 75% of respondents still rate it as of moderate or greater importance. For most capabilities the “no importance” responses are too small to be visible on the graph. These results are consistent with the interview responses described in Butt et al. (2014).

Respondents were then asked to “Describe the extent and quality to which these non-technical skills and capabilities were taught across your actuarial education.” Figure 12 shows the results. Note that a “low” rating here is not necessarily a criticism, since



respondents may feel that particular parts are just not suited to developing a particular capability. That issue is covered in a later question.

In general, Part I is largely viewed as developing non-technical capabilities “Poorly” or “Not at all”, with the exception of Problem Solving, while Parts II and III are viewed more strongly in this area. Perhaps the more practical nature of the latter parts is more conducive to the development of non-technical capabilities. Given that Figure 8 reveals that students believe that the amount of material in Part I is “about right”, any moves to incorporate additional coverage of non-technical skills in Part I are likely to need to be at the expense of some technical material, or requiring university actuarial programs to expand in length. This is consistent with a later question where respondents reported that these capabilities belong better in Part II than they do in Part I.

All parts of the syllabus are viewed as doing a good job at developing problem-solving ability, with broadly similar results across all three parts.

At the other extreme, all parts of the syllabus are viewed as doing little to develop leadership, again with comparable results across all three parts.

The remaining capabilities show more variability by part. Parts II and III are viewed as doing a reasonable job at developing written communication, professionalism and ethics, while Part I does little for these capabilities. The results are broadly consistent for Parts II and III, though with Part II performing noticeably better on ethics. Many Part I university courses place a strong emphasis on producing clear solutions rather than on just getting the final numerical answer correct. Hence the low ratings for written communication suggest respondents may be interpreting that capability as referring only to prose communication rather than also including communication incorporating equations.

Parts I and III are viewed as doing little for oral communication skills. While Part II performs noticeably

better for this capability, only 50% of the respondents still view it as doing at least a reasonable job.

For Parts II and III, about 50% of the respondents view Parts II and III as doing at least a reasonable job at developing anticipation of business trends, noticeably better than Part I.

About 50% of the respondents view Part II as doing a reasonable or better job at developing teamwork skills, with lower results for Part I and significantly lower results for Part III. While some university Part I courses employ group work, which might be viewed as developing the teamwork capability, the assessment scheme for most courses is still strongly biased towards invigilated tests and exams, which may explain the low ratings experienced for the teamwork capability.

Finally, respondents were asked to nominate where they believed the non-technical capabilities should be taught. The full text of this question is as follows:

“Assume now that each of the above non-technical skills and capabilities is important to a significant number of actuaries. We can assume that to some extent these skills and capabilities will be learned ‘on the job’ but need to consider whether they should also be developed within actuarial education. Select below which of the following options represent where you feel these capabilities should be developed and assessed, with the exception that the CPD course option does not involve assessment. You may select multiple options per row. You may also select no options in a row if you do not believe that skill should be developed within formal actuarial education or Institute CPD courses.”

247 respondents completed this part of the survey concerning non-technical capabilities. Table 1 shows

Table 1: Where should non-technical skills be taught?

| | CW | CO | L | PS | P | E | SB | T |
|------------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|
| Separate Part I module(s) | 12% | 10% | 6% | 8% | 8% | 9% | 8% | 7% |
| Integrated into Part I module(s) | 34% | 28% | 12% | 44% | 19% | 22% | 21% | 34% |
| Separate Part II module(s) | 9% | 8% | 4% | 5% | 8% | 8% | 6% | 6% |
| Integrated into Part II module(s) | 48% | 44% | 21% | 49% | 36% | 36% | 36% | 37% |
| Separate Part III module(s) | 3% | 4% | 4% | 3% | 6% | 6% | 4% | 4% |
| Integrated into Part III module(s) | 32% | 28% | 18% | 45% | 34% | 32% | 39% | 23% |
| Institute CPD courses | 23% | 27% | 36% | 16% | 28% | 28% | 30% | 28% |

the percentage of the 247 respondents who nominated each option. Since respondents could nominate more than one option, the numbers in each column can sum to more than 100%.

Perhaps the first thing that stands out here is that no single cell reaches 50%, though several came close. That is, there is no capability/location combination for which we can state that a majority of respondents thought this capability should be taught in this location, although where a choice was made, there is clear preference for integration into existing modules rather than separate teaching of non-technical skills.

However, since the available responses gave options for separate modules or integrating content into existing modules, this tended to “split the vote”. For example, the data above suggests 8% of respondents support teaching problem-solving skills in a separate Part I module and 44% support teaching problem solving skills within existing Part I courses, so 52% support teaching problem solving skills somehow within Part I. In fact, the situation is a little more complex. While we expected “Separate Part I module(s)” and “Integrated in Part I module(s)” to be viewed as mutually exclusive options, a small number of respondents chose both, so adding the 8% and 44% double-counts some respondents. Allowing for this overlap, the proportion supporting teaching problem-solving somewhere in Part I is only 51% rather than 52%. The overlap is small, but Table 2 shows the results after adjusting for it.

Table 2: Where should non-technical skills be taught (collapsed)?

| | CW | CO | L | PS | P | E | SB | T |
|----------|-----|-----|-----|-----|-----|-----|-----|-----|
| Part I | 45% | 37% | 18% | 51% | 26% | 30% | 29% | 41% |
| Part II | 54% | 49% | 25% | 53% | 43% | 43% | 40% | 42% |
| Part III | 35% | 31% | 23% | 48% | 39% | 36% | 41% | 26% |

That is, we can only claim there is majority support for teaching:

- problem-solving skills in Parts I and II, and
- written communication skills in Part II.

More broadly, there is stronger support for teaching non-technical skills in Part II than in Part I or Part III, with the exception of anticipating business trends. Given that the “actuary” designation now includes those who have completed only Part I and Part II, this would seem to indicate a view that non-technical skills should be incorporated at the Associate level.

The discussion above is only one way of interpreting the data. We could investigate if a respondent picked any of Part I, II or III in order to consider whether the respondent thought the non-technical skill should be taught in any part of formal actuarial education. In fact, the clearest point to emerge from the spread of the results in Table 2 is that there are significant differences of opinion as to if and where non-technical skills should be taught in formal actuarial education.

So, to briefly summarise the opinions on the non-technical capabilities, respondents think most the capabilities are important to their work; they think the current Parts I to III don’t do a good job of teaching most of them, but there are no clearly appropriate locations for teaching these capabilities.

2.8 The relationship between Part I, II and III

First, Figure 13 presents a word cloud from the 91 responses received to the question “Comment on the appropriateness or otherwise of the relationship between Part II and Part I”

Respondents clearly believe that Part II is designed to be an opportunity to practically apply the technical material learned in Part I. One response that captures this well stated:

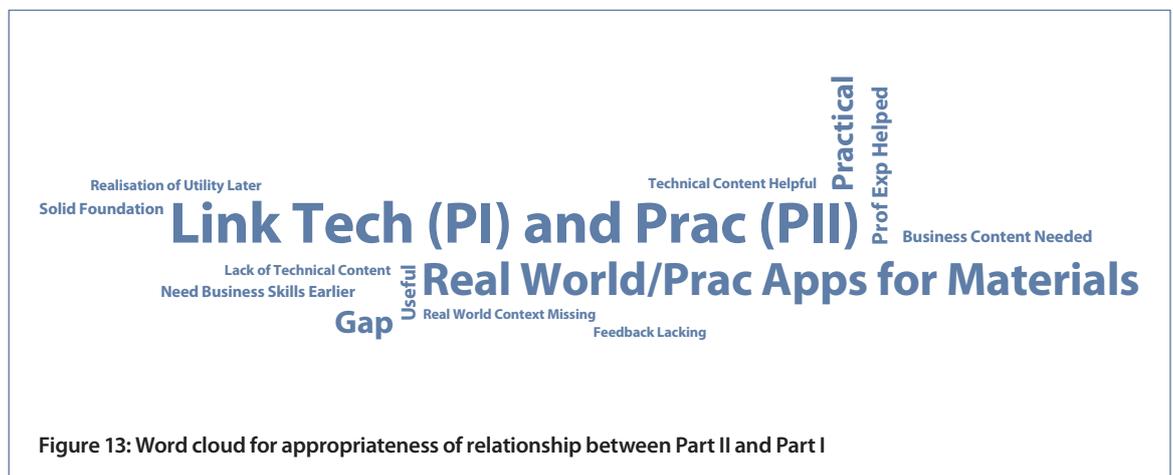


Figure 13: Word cloud for appropriateness of relationship between Part II and Part I

“I feel it is a very good split between technical skills where answers are black and white and the practical, less strict applications of these skills in part 2. Though we don't actually apply the technical processes from part 1, part 2 genuinely helped to bridge the gap and helped me develop a sense of clarity with regards to how the skills I learnt will add value to business problems.”

However, a number of respondents felt the break was too significant and that the jump between Part I and Part II was very difficult to cope with. These respondents tended to suggest that some of the business focus of Part II be incorporated into Part I to lessen the jump and to make the Part I material more clearly relevant. However, both Part II and Part I are seen to be relevant, as one response stated:

“There wasn't a clear relationship between the two – Part I was very focused on actuarial techniques and Part II was focused on actuarial management. There wasn't really a connection in applying actuarial skills to the real world. It was also somewhat difficult to study Part II after having three years of mostly mathematical subjects. Perhaps Part II could be integrated more closely with Part I so that for those undertaking four years of undergraduate study, you don't have such a huge difference between the type of subjects studied in third year (say) compared to fourth year. Would be difficult to change though.”

Only 34 responses were received to the question “Do you have any comments on the appropriateness of otherwise of the relationship between Part III and the other Parts of actuarial education” and many of these commented on a specific Part III course rather than Part III as a whole. Hence a word cloud is not presented. Some representative quotes stated:

“I think Part II is a good happy medium between Part I and III. It starts putting things on perspective. Though I think it'd help if the Part I were tailored to link to practical reality too.”

“Part III is an excellent way to learn how to combine technical skills and business advice (in particular CAP). It teaches communication and how actuaries can really add value in an organisation – combination of strong technical ability and ability to interpret results and findings that are appropriate to their clients. Part I taught students the basics of analysis and learning techniques. Part II provided a practical, but mostly non-technical view of Actuarial work. Part III represented the practical 'real world' education in application of technical knowledge and problem solving. It is a great way of combining everything learnt from Part I and Part II, and using this knowledge to solve business problems.”

Respondents to the open-ended questions were largely happy with the purpose of Part III, as compared with Part II and Part I, even if previous questions indicated they weren't happy with the implementation of Part III.

3 CONCLUSIONS AND IMPLICATIONS FOR ACTUARIAL EDUCATION

Different subjects within the Part I exams are designed to be useful in different practice areas. Generally, respondents are supportive of the material in the Part I subjects relevant to their current area of employment, with the unsurprising result that those working well outside traditional areas of employment for actuaries find less value in Part I. Finding a balance between catering to traditional actuarial work, while meeting the needs of an ever-growing non-traditional workforce, will be an ongoing challenge to those making decisions on content in the Part I syllabus.

For Parts I and II, respondents are happy with most aspects of the courses, with feedback being the area most needing improvement. Provision of feedback is one of the more time-consuming aspects of course delivery, so achieving improvements in this area can be costly.

Respondents are less positive about Part III, with syllabus content being the only factor scoring highly. The smaller numbers in many Part III subjects are likely to make the cost/quality trade-off a challenging exercise.

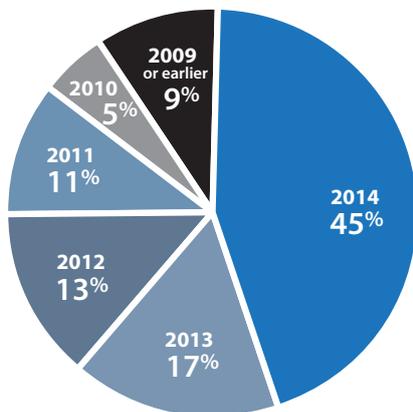
More surprisingly, respondents are generally happy with the amount of material in all parts of the exams.

Respondents strongly support the usefulness of non-technical capabilities in their careers, but there is not clear support for including most in any specific location in the examination process, although there are a wide variety of opinions on this issue. While it is a slim majority, there is majority support for including the problem-solving capability – arguably the most technical of these non-technical capabilities – in Parts I and II, but there is also a very strong opinion that this has already been achieved. There is also majority support for teaching and assessing written communication skills in Part II, also with a strong opinion that this is already being achieved.

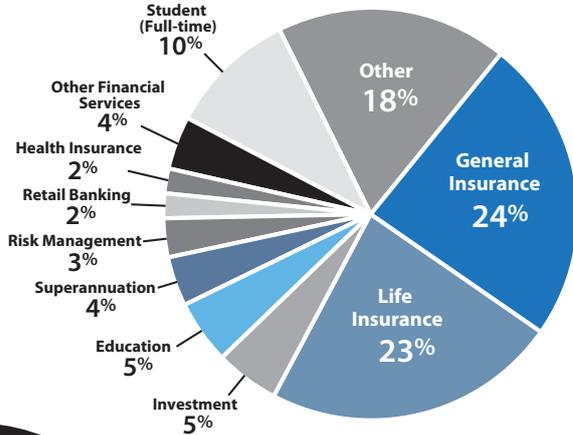
We consider this survey to be a starting point for further investigation of areas of improvement for actuarial education. From the results of this survey, the key areas for further investigation and consultation with relevant stakeholders are:

- what technical material to include in Part I
- how to manage the transition between Part I and Part II
- improvement of the delivery (although not necessarily the content) of Part III
- the appropriate location (if any) for teaching of non-technical skills

Year of Most Recent Actuarial Examination



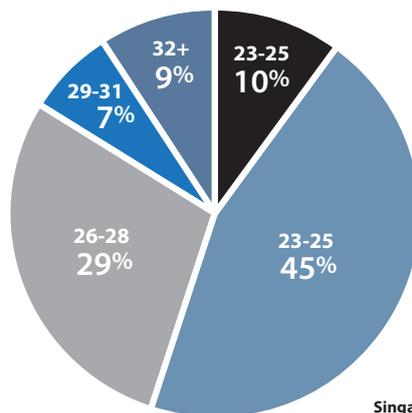
Current Employment Area



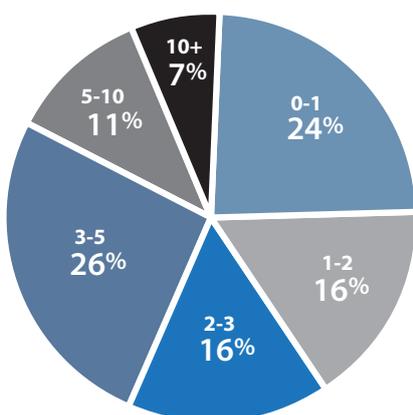
APPENDIX

These pie charts summarise the demographic features of the respondents.

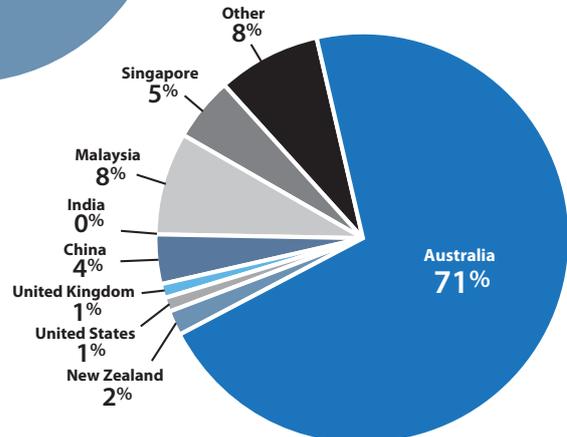
Age



Years of Full-Time Work Experience



Current Employment Location



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The tale of negative yields

CELESTE CHAI



Celeste Chai

INTRODUCTION

In recent times, a new and topical trend has emerged: negative interest rates. Interest rate related securities, such as bonds, rely on central banks' deposit rates as a benchmark. When these deposit rates fall below positive, there is a corresponding drag on the yields of these assets. In this topsy-turvy world where investors are paid interest to take out a mortgage and businesses to take out a loan, how do negative interest rates affect different market participants? Do negative rates achieve their desired economic outcome, and can they be expected to linger? To answer these questions, this article presents a detailed background of negative rates. Next the article provides an assessment of the current economic situation relating to negative rates, focusing in particular on Europe and Japan. Finally, the potential impacts to Australia and life insurers are considered and suggestions are made to address these challenges.

BACKGROUND

Monetary Policy

Central banks use monetary policy to set the interest rate and achieve economic stability for a variety of economic factors including inflation rate, unemployment rate and currency. In expansionary monetary policy, lower interest rates make loans and mortgages cheaper. This policy incentivises businesses to borrow and thereby stimulates the economy. Additionally, a lower interest rate makes it less attractive to hold deposits in the country, resulting in net currency outflow and a falling exchange rate. Exports become cheaper and demand increases, which also stimulates the economy and aids in sustaining healthy levels of inflation. The reverse occurs in a contractionary monetary policy.

Negative interest rates are not a new phenomenon. In principle, there are no constraints on the level of deposit rate or cash rate set by central banks and setting a rate below zero poses neither procedural nor operational difficulties. Traditionally, when interest rates are near or at zero, this results in a zero lower bound liquidity trap. This serves to limit the central banks' capacity

KEYWORDS

negative yields, quantitative easing, monetary policy, deflation.

for monetary policy by influencing the interest rate. However, a new occurrence, known as the negative interest rate policy (NIRP), contradicts zero as the lower bound. Under NIRP, central banks take more drastic measures by penalising deposits and rewarding borrowings.

A negative yield on a bond implies that an investor is paying to lend their money and will not get all their money back on this investment. Even though the logic appears irrational and counter-intuitive, bonds with negative yields can remain viable investment tools. If yields continue to fall, investors benefit from a rise in bond prices and a purchase of an asset at a higher yield (less negative) than prevailing yields (more negative). The current inflationary environment also plays a part. If yield is greater than inflation, the investor would make real returns on the bond(s). It is also important to point out that although yields, particularly at the short end of the yield curve, are below zero, the upward sloping shape of the yield curve is maintained. An AAA-rated government bond (with no credit risk) incorporates an additional illiquidity premium, which increases with term structure. Hence, under these circumstances, the bond returns would be superior to cash deposit returns.

When Monetary Policy Fails

Monetary policy becomes ineffective when the targeting of interest rates fails to achieve the desired outcomes. In recent times, stagnant or poor economic growth (i.e. recession) has seen individuals save more, and created a continued downward spiral of reduced aggregate demand and consumption. Accordingly, general prices fall and deflation follows. This is known as the Paradox of Thrift, an economic concept popularised by John Maynard Keynes. These outcomes conflict with the initial purpose of expansionary monetary policy.

In response, central banks can choose to exercise NIRP. In contrast to low or zero interest rates, depositors are penalised for deposits and rewarded for borrowing. However, cheap mortgage costs promote the formation of housing asset bubbles which poses additional economic instability risk. Cash hoarding behaviour is encouraged which is costly as individuals incur additional costs such as safety deposit box fees in order to store the cash and daily activities can become cumbersome.

Alternatively, unconventional monetary policies such as quantitative easing (QE) can be implemented.

Central banks increase money supply and purchase longer dated financial instruments (i.e. bonds) which artificially inflates bond prices. Bond yields decrease when bond prices increase. While NIRP reduces yields at the short end of the yield curve, QE exerts downward pressure at longer maturities further out the yield curve which disincentivises savings and promotes lending over lengthier time frames.

CURRENT ECONOMIC SITUATION

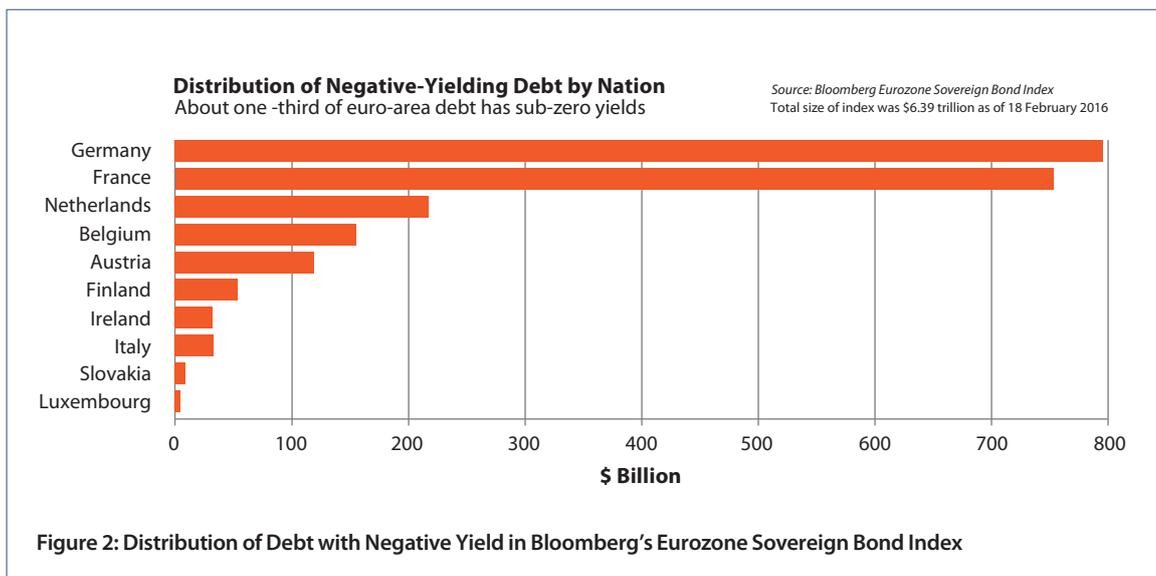
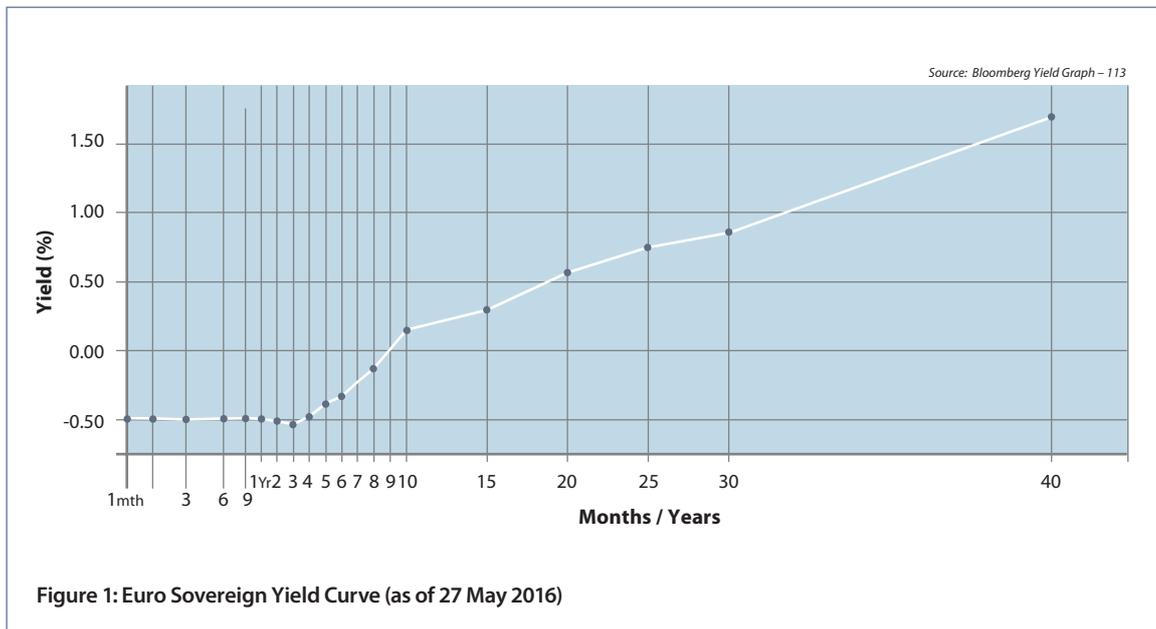
The current economic cycle is characterised by QE policies. Most developed countries have executed at least one round of bond buying programs. The United States (US) was the first of the developed countries to introduce zero interest rates and QE in 2008. Recent improvements in economic data prompted the Federal Reserve, US's central bank, to implement the first rate hike of 0.25% since 2006. Similarly, the Bank of England (BoE), terminated its bond purchasing policy in 2012, three years after its commencement. The same cannot be said for Europe and Japan, two major economies still in the midst of monetary expansionary NIRP and QE policies. As such, these two countries form the core of the discussion below.

The Situation in Europe

Starting in 2011, high unemployment rates and deflationary fears drove the European Central Bank (ECB) to implement expansionary monetary policy to stimulate the European economy. Subsequently, the ECB deposit rate fell below zero to -0.2% in June 2014 and has remained negative since. In essence, the ECB pays financial institutions like banks to borrow from the ECB in order to boost commercial onward lending. The ECB commenced its QE program in March 2015 by purchasing sovereign bonds from Eurozone governments and financial securities from institutions and national agencies.

As shown in Figure 1, the sovereign Euro yield curve, the benchmark reference yield curve for Eurozone countries, has negative yields for maturities of up to 9 years. Since November 2015, approximately one-third of all Eurozone government debt has negative yields. Figure 2 shows the distribution of sovereign debt with negative yields in Bloomberg's Eurozone sovereign debt index. As bond purchases from the QE policy is proportionate to the country's size, Germany and France have the largest share of sovereign debt with negative yields¹.

¹ On a side note, Sweden's main currency is the Krona (rather than Euro) despite being a European Union (EU) member and its central bank, Riksbank, was the first European central bank to apply NIRP in 2009. The Swiss Federal Treasury also became the first government in history to sell benchmark 10-year bonds at negative yields (yield = -0.055%) in April 2015. Interestingly, although bond investors would be paying interest on lending their money, the Swiss bond issue was fully subscribed.



The Situation in Japan

It is suggested that the term 'quantitative easing' was born in Japan during the five-year period starting in 2001 when the Japanese government attempted and failed to stimulate economic growth. The Bank of Japan (BOJ), Japan's central bank, began the latest round of QE in April 2013. The QE programme was recently enhanced in October 2015 from ¥60 – 70 trillion to ¥80 trillion of annual bond purchase. Despite this, inflation persistently remains low and consumer spending poor. This motivated an announcement on 29th January 2016 by BOJ to introduce negative deposit rates of -0.1% on excess funds. This move was unexpected by financial markets, resulting in a sharp fall in the Japanese

sovereign yield curve and currency alike. As shown in Figure 3, the Japanese sovereign yield curve only becomes positive at maturities above 14 years.

Future Outlook

The success of NIRP and QE policies is sporadic at best. Inflation in the Eurozone remains low and below targeted levels. This has triggered further action by the ECB in December 2015, cutting the deposit rate by ten basis points to -0.30% and extending the original September 2016 QE deadline by at least six months. Again, these measures did not achieve the desired outcome and a deflation rate of 0.20% was recorded in February 2016. The following month, the ECB

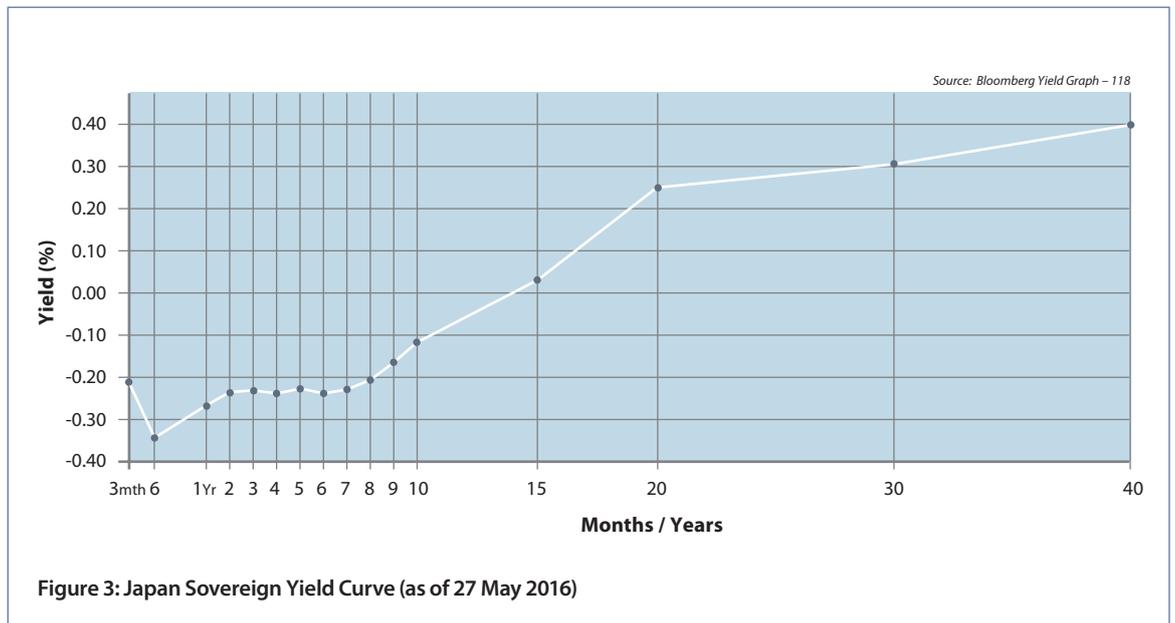


Figure 3: Japan Sovereign Yield Curve (as of 27 May 2016)

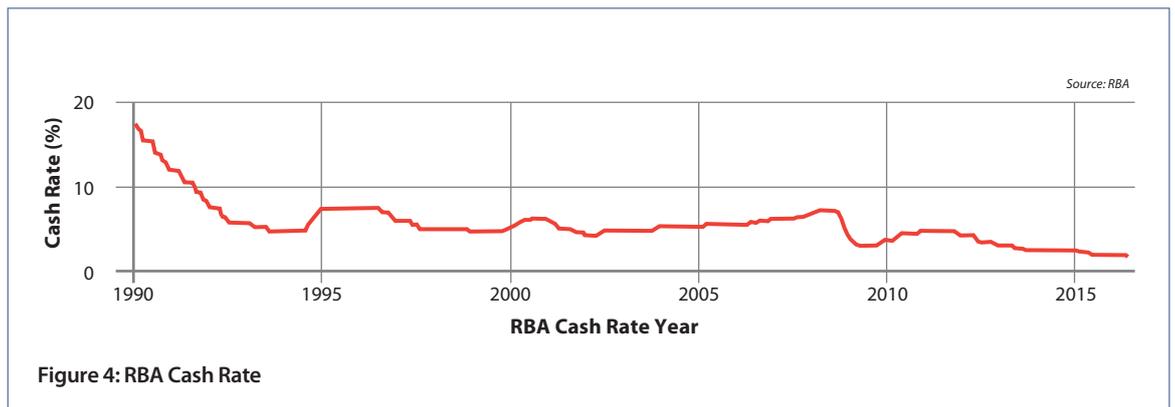


Figure 4: RBA Cash Rate

responded by cutting deposit rates further to -0.40% and increasing its monthly bond purchases from €60 billion to €80 billion.

Likewise, Japan experienced two consecutive months of deflation in March and April 2016 with weak year-on-year consumer spending at -5.3% for March 2016. These statistics have given rise to conjecture about further stimulus at the upcoming BOJ meeting in June 2016.

With no hard limit on the depth of negative rates, it is difficult to foresee an end to negative rates in the near future. Negative interest rates are evolving from a passing occurrence into a longer term reality that must be seriously addressed.

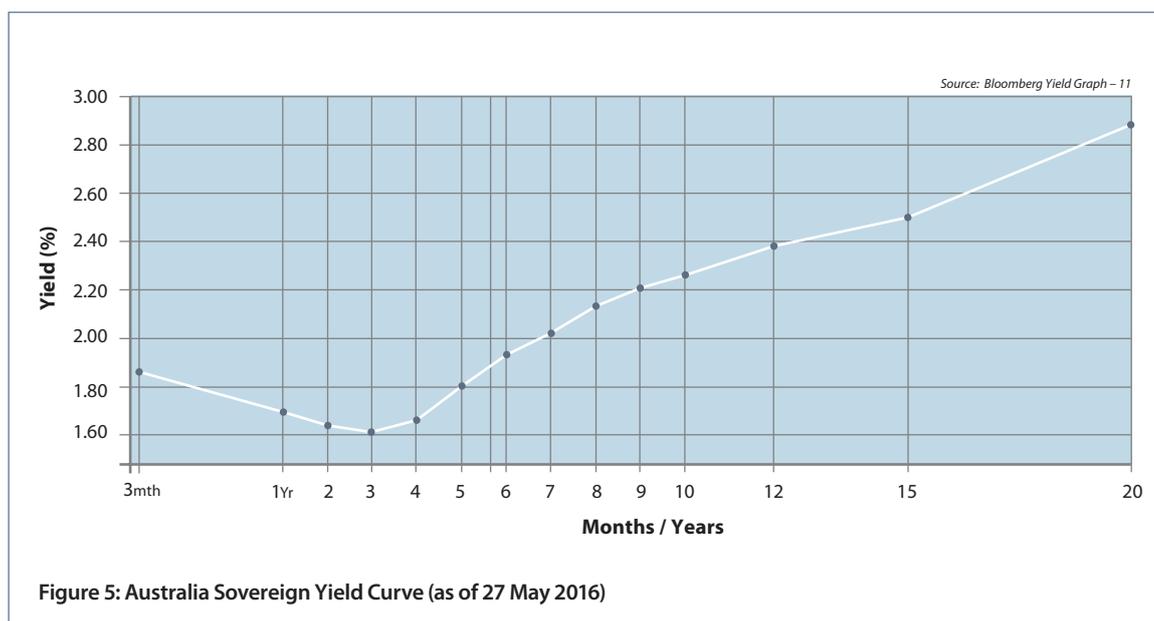
AUSTRALIA'S ECONOMY

Australia's economic situation is nowhere as grim as that of Europe nor Japan. However, the situation remains fortuitous. Figure 4 illustrates the historical

cash rate set by the Australia's central bank, the Reserve Bank of Australia (RBA). The RBA cut the cash rate in May 2016 to a record low of 1.75% on the back of deflationary statistics for the first time in seven years. Ten year government yields fell to record lows of 2.2% (see Figure 5), the lowest in 141 years.

Globalisation has increased the correlation between global economies and the trend of falling interest rates is as much an international as domestic story. Continual monetary easing by ECB and BOJ exerts downward pressures on the Euro and Yen, making the Australian dollar appear more expensive in comparison. This currency conflict puts the RBA under pressure to copy the actions of other central banks in order to maintain price competitiveness of Australia's exports.

While economists remain divided over the possibility and timing of further RBA rate cuts and what the floor is, it is prudent to recognise the low interest rate cycle Australia is trapped in and provide measures to cope with it.



IMPACT TO INSURERS

Bonds have traditionally been presented as a secure financial investment. The yield of a bond can be locked in if the bond is held to maturity, with certainty over coupons and maturity payment. Bonds are favourable investment options as they provide a higher return over cash and exhibit historically lower volatility than assets classes like equity. Yet, at low (or negative) yields, the returns from these investments might be insufficient to match insurers' liability requirements. A margin squeeze results, causing additional demand on capital reserves and possibly solvency difficulties.

There are a number of mechanisms for insurers to cope with the existing low yield environment. As the yield curve is upward sloping moving further along the yield curve at longer maturities will improve yield returns. However, duration increases when yields fall and this method of chasing yields will exacerbate the asset-liability duration mismatch. If yields were to subsequently rise, causing a fall in asset value, losses can be incurred from premature asset sales prior to maturity.

Holding cash assets is an equally unlikely alternative. When bond yields are negative, cash returns are also likely to be very low or negative. Additionally, the deposit fees at bank facilities may be prohibitive, and paying policyholders in cash is operationally challenging.

The risk-reward relationship suggests that higher returns can only be achieved from greater risk taking. Insurers can tilt their investment strategies towards riskier asset classes to chase superior returns but with no guarantee that these returns outcome will eventuate. Nevertheless, the increased risk profile will result in a

corresponding increase in capital requirements and solvency risk will escalate. The mismatch between asset and liability duration continues to worsen.

On all fronts, a low-yield environment creates complications, and insurers need to remain vigilant. There is no single ideal investment strategy which suits the needs and capabilities of each insurer. Insurers should be aware of the possibilities available at their disposal to manage these challenges and execute the most appropriate line of action.

CONCLUSION

The recent occurrence of negative yields is a historically atypical phenomenon. Nevertheless, deflationary concerns are forcing central banks to implement expansionary monetary policies including NIRP and QE, which encourages the prevalence of negative interest rates. When this occurs, financial markets are in a turbulent ride where investors are rewarded for loans and penalised for deposits. This could lead to cash-hoarding behaviours and housing asset bubbles. Though Europe and Japan are the main patrons of negative yields, Australia is also facing deflationary and currency concerns. It is hard to predict the end of the existing low interest rate environment. Therefore, insurers should consider alternatives available to them in preparation for new obstacles emerging.

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