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The Australian retirement lottery: a system failure

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Keywords

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The Australian Retirement Lottery: A System Failure

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Abstract

The purpose of this paper is to assess the adequacy of the Australian retirement system to fund the needs of retirees by taking into account both the Knightian risk arising from market volatility under normal market conditions as well as the Knightian uncertainty arising from rare but severe market shocks. We have also taken into account changes in employment during the pre retirement phase. Given the low frequency, high impact of market shocks, the result is that cohorts of Australian retirees will enjoy very different levels of retirement income and there will be consequent shocks to the demand for the Age Pension supplement and potentially, significant variations in the standard of living in retirement for Australian employees. Whilst the Australian retirement system has been put forward as a model for other economies to follow, we find there is a fundamental flaw in the system.

JEL Classification: C5, I31, G17, G18

Keywords: Superannuation Guarantee Levy, Retirement Funding, Market Shocks, Econometric modeling

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1. Introduction

The retirement system in Australia has changed considerably over the last hundred years evolving into a 'three pillar' structure (see Nielson & Harris, 2010 for a chronology of retirement income policies in Australia). The first pillar is the Government Age Pension which is a means-tested defined benefit pay-as-you-go (PAYG) pension. The second pillar is the 'Superannuation Guarantee' (SG), which is a mandatory contribution pillar where employers contribute 9.25% of the ordinary time earnings of the employees to a superannuation fund. The third pillar is voluntary savings either through tax preferred superannuation funds, owner-occupied housing or non-tax preferred saving instruments such as bank deposits, term deposits, shares etc.

Each pillar is designed to achieve different policy goals. The focus of the first pillar is poverty alleviation and wealth redistribution. The mandatory second pillar is designed to smooth the life-cycle consumption by dealing with the unwillingness to save due to shortsightedness and myopia. The third pillar provides a means for savings by those who wish to have additional savings to fund retirement. The second pillar was only introduced in 1991 and therefore most individuals retiring at present have not benefited from a full working life under the mandatory saving system. However, once the SG system matures it is expected that for an *average* individual the bulk of the retirement income would come from the second pillar, with the third pillar supplementing the retirement income, and the Age Pension functioning as a safety net.

Whether the SG contribution rate is capable of delivering an adequate retirement income has received considerable amount of attention over the years. Academia, industry groups, professional bodies, as well as the Government Treasury have contributed to the ongoing dialogue. Recent work published by Treasury indicates that they considered the then current SG level of 9% was adequate (see Gallagher, 2011; Rothman, 2011). Rothman (2011) projected the expected replacement rates² for the entire Australian population using the Treasury's RIMGROUP³ model. After taking into account the Better Super reforms, the 2009 increase in Age Pension payments, reduced

² *Replacement Rate* = $\frac{\text{Disposable retirement income}}{\text{Disposable income immediately before retirement}}$, and is discussed more fully in Section 2 of this paper.

³ The RIMGROUP is a cohort projection model which tracks the labour force dynamics, different contribution rates, salary sacrifice arrangements, superannuation accumulations, estimate non-superannuation savings, tax expenditure etc. separately for each birth-year gender decile cohort (Rothman 2011)

superannuation balances due to the Global Financial Crisis (GFC), the foreshadowed increase in Age Pension eligibility age, announced gradual increments in the SG contribution rate, and the latest demographic trends, the authors concluded that a rise in the SG to a 12% level would provide most retirees with replacement rates of 80% or more after 20 to 25 years in the system. In a separate study Gallagher (2011) carried out hypothetical analysis using the Government Treasury's RIMHYPO model and reported similar results. The Henry report (Australian Government Treasury & Henry, 2009) is also another notable publication based on the RIMHYPO model which concluded that the 9% SG contribution rate was sufficient to achieve adequate retirement levels. The panel reported that an individual who started working in 2000 at the age of 30 years, and earned the average weekly ordinary time earnings (AWOTE) would achieve a replacement rate of 62.9% when he retired at the age of 65. A similar individual who earned 75% of AWOTE would achieve a replacement rate of 73.4%.

CPA Australia is one of the professional organizations that have contributed to the debate of the adequacy of superannuation funding. On several occasions CPA Australia has commissioned the National Centre for Social and Economic Modeling (NATSEM) to research the adequacy of the current superannuation arrangements. The 2007 report prepared by NATSEM for CPA updates and extends their previous work by incorporating the Better Super changes that commenced in July 2007. In their report Morrison and Kelly (2007) analysed four family types (a single male, a single female, a couple without children, a couple with two children), under three different income levels using the 'Australian Population and Policy Simulation Model' (APPSIM)⁴ developed by NATSEM. Under the base case scenario, which the authors suggest as the "most likely superannuation and lifetime choices for the modeled cases", they found that all 12 households would have '*modest but adequate*' (MBA) income during retirement provided that the 9% SG contributions were made for 40 years. For the base case scenarios the authors assumed a 4.5% real return on the superannuation funds. They carried out sensitivity analysis by changing the real returns by one percentage point. They found with a 1% decrease in real returns all 12 households will still be able to maintain the MBA standards.

⁴ APPSIM is a 'hypothetical lifetime' dynamic micro simulation model. More details of the model can be found at <http://www.natsem.canberra.edu.au>.

Keegan et al. (2011) is a more recent paper which uses the APPSIM model. In their paper the authors projected the account balances for individuals under a mature superannuation system in 2051. The authors estimated that the median balance in 2051 for a male aged 64-66 with 40 years of contribution history to be \$424,700 and for a similar female \$297,000 (in 2006 dollar terms). The paper does not comment on the replacement rates nor the age pension payments. However, using the 2014 annuity rates quoted by Challenger⁵ for fully CPI indexed lifetime annuities we estimate the aforementioned male could buy a CPI indexed life annuity which pays \$22,866 pa and the female could buy a CPI indexed life annuity which pays \$15,406 pa.

An interesting industry model which has contributed to the ongoing debate is the AMP Retirement Adequacy Index prepared by the Access Economics which compares the average post-retirement consumption spending of Australians to their average consumption spending in the final year of work, after adjusting for taxes and savings. The index is calculated by projecting superannuation balances of more than 328,000 members of superannuation funds managed by the AMP. One important feature of the AMP retirement index is the source of data they use to calibrate their model. Since the data is drawn directly from client records rather than surveys and sampling, they are able to measure contributions and superannuation balances to a high degree of accuracy. Access Economics indicates that "the index can be thought of as a combined account 'statement' for Australian super fund members" (p18, Access Economics, 2009). As of June 2010 the index value was at 71.4% which is significantly higher than the target rate of 65%. However, it is worth pointing out that the AMP report is based on AMP superannuation population, and may not be representative of the broader population since it underrepresents the people not covered by the SG system such as non-workers and self-employed. In an earlier more detailed report, AMP reported that although average individuals are likely to achieve the target level of 65%, more than 40% of young workers would fall below the target level of adequate income (AMP, 2009). This raises serious concerns in terms of the adequacy of current saving levels for certain income groups.

The Investment and Financial Services Association (IFSA) is another industry group which has raised concerns over the adequacy of retirement savings of Australians. In the past IFSA has

⁵ Challenger web page 23 January 2014 <http://www.challenger.com.au/products/rates.asp>

commissioned Rice Warner Actuaries to project the national 'Retirement Savings Gap'⁶ using an aggregate model. According to Rothman (2011), Rice Warner's aggregate model is the closest model to Treasury's RIMGROUP model amongst the other Australian aggregate models. However, in contrast to the Treasury aggregate projections, Rice Warner Actuaries project that there is a Retirement Savings Gap of \$695 billion as at 30-Jun-2008, based on a target replacement rate of 62.5% (Rice Warner Actuaries, 2010b).

A serious limitation of the previous work is that there has been limited attention given to the stochastic nature of economic variables affecting the retirees' account balances. Most studies have assumed deterministic rates for investment returns, inflation and wage growth. No serious work has been done to quantify the impacts of market crashes such as occurred during the GFC. Though it is possible to project expected income replacement rates by making deterministic assumptions about the long-term economic variables, they do not provide any information regarding the likelihood of replacement rates falling below the target rates, nor do they show that different cohorts of retirees could have very different standards of living in retirement. In other words, previous studies have done very little to properly quantify the risks faced by the retirees due to Knightian uncertainties⁷ inherent in the SG component of the Australian retirement system.

In this paper we will analyse the ability of the first and second pillar of the Australian retirement system to provide retirement incomes for differing cohorts of retirees under Knightian certain risks and Knightian uncertain market conditions. To achieve this objective we have built an economic scenario generator for the Australian economy which can simulate realistic future economic

⁶ The Retirement Savings Gap is defined as the difference between national private savings required to achieve an 'adequate' savings in retirement and projected savings in the superannuation system. Income in retirement above a replacement rate of 62.5% for individuals and 75% for couples is considered 'adequate' by IFSA.

⁷ The Knightian framework by Ganegoda and Evans (2012) is a framework designed to classify various types of risks for better understanding and management of risks. It contains four realms of uncertainties, namely, Knightian Risk - the risks that we know exists and can model with confidence; Knightian uncertainty - the risks that we know exist but cannot model with confidence due to limitations in data and theory; Ambiguity - where we know the risk exists, but recognize that there is a range of outcomes, each of which can be modeled, but where we are uncertain as to which outcome will occur due to the difficulty of predicting human actions and counteractions; Ignorance - where we have no idea what risks exist.

scenarios and hence reflect the Knightian certainty risks, and then incorporated market crashes to reflect the inherent Knightian uncertainty.

2. Measuring Adequacy

Finding a global benchmark which defines '*adequate*' retirement income is a difficult task since what is '*adequate*' will depend on the individual's life style, health status, and other individual preferences. Past research has used many different definitions and measures of adequacy, and this is one of the main reasons why different studies have arrived at different conclusions about the adequacy of retirement incomes. Rothman (2011) points out that adequacy of retirement income can be measured using either a relative framework or a budget framework. The relative framework utilizes the concept of replacement rates or expenditures relative to a poverty or a standard of living benchmark, whereas the budgetary framework attempts to quantify the actual cost of living for a retiree..

2.1. Replacement Rates

Replacement rates compare the standard of living before and after retirement by using the ratio of the post-retirement expenditure to pre-retirement expenditure. Though it is a relatively simple idea there is no consensus on what is the best way to calculate replacement rates. Many key groups such as the Government Treasury (Rothman, 2011), the Institute of Actuaries (IAAust, 2002), and NATSEM⁸ (Morrison & Kelly, 2007) have used net potential expenditure to calculate the replacement rates, while some groups such as IFSA and Rice-Warner have based their replacement rates on gross pre-retirement earnings. Rothman (2011) points out that the replacement rates calculated from gross earnings can be misleading due to substantial differences in taxation and savings before and after retirement for different income groups.

The adjustment for inflation is another factor which plays an important role in the final results. Rothman (2011) demonstrated that when average expenditure in retirement or working life is used

⁸ NATSEM uses discretionary income of individuals, which equals "*gross income plus welfare payments minus tax minus housing costs minus employee's super contributions*" (p4, Morrison & Kelly, 2007).

to compute replacement rates, use of average weekly earnings as opposed to the consumer price index (CPI) as the deflator significantly reduces the replacement rates.

The main advantage of using replacement rates to measure adequacy is that it provides a clear relationship between the before and after retirement spending power. However, the main drawback of the measure is that it does not provide any information regarding the absolute standard of living, which is particularly affected by whether the retiree is renting or a home owner and it is possible for a person to be living in poverty and still have a high replacement rate.

2.2. Budgetary Standards

A budget standard focuses on the income needed to maintain a pre-determined standard of living. The current leading budget standard used in Australia is the ASFA Retirement Standard. The ASFA standard was first introduced in 2004, but it finds its roots in a major budget standard study carried out by the Social Policy Research Centre of University of New South Wales in 1997-1998 (Saunders, Patulny, & Lee, 2004). In the latest version, two benchmarks are calculated to maintain a *modest* standard of living and a *comfortable* standard of living. A modest standard of living is defined by ASFA as slightly better than living solely on the Age Pension, but only being able to afford basic needs. The comfortable standard of living assumes a desire to have a range of leisure activities, and to be able to purchase goods and services such as health insurance, a reasonable car, and good clothes. Both standards assume retirees own their home outright and are in good health (ASFA, 2011).

The main advantage of a budget standard is that it is based on actual cost of living. Thus, it can be used to determine whether an individual has enough savings to afford a given standard of living. However, the main drawback of the measure is that it is not related to individuals' pre-retirement income levels. Furthermore, budget standards are difficult to project into the future since it is impossible to determine future technologies and their impact on cost of living.

In this study we will use replacement rates as well as budget ratios to measure the adequacy of retirement income. The definition of replacement rate used for this study is

$$\text{Replacement Rate} = \frac{\text{Disposable income received from an indexed life annuity bought upon retirement}}{\text{Worker's final year disposable income}} \quad \text{(Eq.1)}$$

where, disposable income is defined as the income after paying taxes and the indexation reflects changes in wages. We consider a replacement rate of 62.5% would provide adequate retirement incomes, which is the target replacement rate used by Rice Warner Actuaries (2010a).

The definition of the budget ratio used in this study is

$$\text{Budget Raio} = \frac{\text{Disposable income received from an indexed life annuity bought upon retirement}}{\beta \times \text{Male AWOTE at time of retirement}} \quad \text{(Eq. 2)}$$

where, β is a constant which represents the standard of living at retirement. We set β using (Eq. 3) and the values for β are given in Table 1.

$$\beta = \frac{\text{ASFA budget requirement for a comfortable standard of living as of Dec-2010}}{\text{Annual income of a male earning AWOTE in the 4th quarter of 2010}} \quad \text{(Eq. 3)}$$

Table 1: Values for β using ASFA Budget Standard and AWOTE for the 4th quarter 2010

	ASFA Comfortable Retirement Standard	β
Single	\$39,393	55.8%
Couple	\$53,879	76.4%

3. Analysis Methodology

We have analysed the adequacy of the superannuation system by assuming a *mature*⁹ SG system for a single male and a married couple. To enable us to carry out the analysis, we have developed an economic scenario generator for the Australian economy which can simulate six economic variables¹⁰. The simulated values of the variables are used to calculate the superannuation account balances by making assumptions about the employee profile, salaries, contribution rates, taxes, fees & charges, and asset allocation. Finally the adequacy measures are computed by making further assumptions about the decumulation of assets. All simulations are carried out in real terms. This Sections provide a detailed discussion of the assumptions used in the base case scenario. In Section 5 some of the assumptions made in the base case will be changed to analyse variations to the base case results.

3.1. Employee Profile

We consider a hypothetical single male and a married couple in our analysis. The single male is assumed to start working in 2010 at the age of 25. He works for 42 years and retires in 2052 at the age of 67. For the couple, we make the simplified assumption that both the male and female are of the same age and start working in 2010 at the age of 25, work for 42 years and retire in 2052 at the age of 67. The retirement age was chosen to be in line with the Age Pension eligibility age¹¹ and we assume as soon as the individuals retire they will receive the Age Pension if they pass the means tests.

⁹ The SG rate was increased to 9 per cent in 2002. Therefore, we assume the superannuation system matures in 2051 when people who were 18 years old in 2002 will be eligible to receive Age Pension.

¹⁰ See the Appendix for details of the econometric variables used and the comparison of our estimated values against actual.

¹¹ Under the 'Secure and Sustainable Pension reforms' introduced by the Australian government in 2009 federal budget, Age Pension eligibility age for men and women will gradually increase up to age 67 by 1st July 2023.

3.2. Employment Status

Individuals may have periods in their career in which they are not employed as a result of layoffs, periods between change of jobs, and leaving the workforce to raise children when SG contributions will not be paid. In our model, for simplicity, we have assumed three possible employment status: (i) employed, (ii) unemployed, and (iii) non-employed¹².

Employment is modeled using a categorical random variable with each state representing an employment/unemployment duration as given in Table 2 and a probability of being in one of those states as given in column two and three. We estimated the probabilities of different unemployment durations by computing the average unemployment rates for the period September 1997 to December 2010 using ABS (2010b), and then standardized each category such that the total unemployment probability matched the long-term unemployment rate. We have not attempted to include a further variable relating to periods of partial employment which would also affect the SG retirement benefit due to paucity of reliable data.

Table 2: Unemployment Probabilities and Durations

Level	Standardized Probability of Unemp.		Duration of Unemp. (weeks)	
	Male	Female	Male	Female
Employed	0.9422	0.9325		
Unemp. < 4 weeks	0.0144	0.0191	1.6	1.6
4 weeks ≤ unemp. < 13 weeks	0.0164	0.0203	7.1	7.1
13 weeks ≤ unemp. < 26 weeks	0.0104	0.0114	18	17.9
26 weeks ≤ unemp. < 52 weeks	0.0096	0.0102	35.6	35.3
52 weeks ≤ unemp. < 104 weeks	0.0068	0.0065	68.2	67.1

3.3. Salaries

Most of the previous studies on retirement adequacy have assumed salaries remain equal to the AWOTE throughout the individual's career. Though relatively simple this assumption ignores some important facts with regard to a typical age-earnings profile. It is common knowledge that the

¹² A person is classified as unemployed if the person is not currently employed but actively seeking for a job, and non-employed if the person is out of the workforce and not seeking a job.

individual earnings depend on the work experience as well as the overall condition of the economy. Therefore, the assumption of a flat age-earnings profile is unrealistic. In order to address this shortcoming we modeled earnings by decomposing the changes in earnings into two components: firstly, the changes in personal earnings due to changes in the general level of earnings in the economy, and secondly, the changes in personal earnings due to changes in individual's productivity.

The main drivers of the first component are inflation and changes in the general productivity of the economy. The drivers behind the second component are more difficult to determine since it depends on the personal circumstances of the individual. Given everything else remains the same it is reasonable to assume that the individual productivity is a function of age as a proxy for work experience. Empirical research has found that salaries usually grow rapidly during the early stages of a career, peak in mid-life, and then slow down at the later stage of a career (see for example, Blake, Cairns, & Dowd, 2001; Gilbert, 1994; Murphy & Welch, 1990). We have taken into account this lifetime concave earnings schedule for individuals by including an age-earnings ratio (AER) to determine salaries. The method to simulate salaries for a male is explained below. Salaries for a female have been simulated analogously.

We define the age-earnings ratio (AER) for a male aged x with a given education level as

$$AER(x)_M = \frac{\text{total earnings at age } x \text{ for a given education level}}{MTAWE}$$

where, $MTAWE$ is the male total average weekly earnings. Then assuming age-earnings ratios $AER(x)_M$ remain constant over time¹³, we can determine the total earnings for a male at age x in the time period t as

$$W(x)_t = MTAWE_t \times AER(x)_M \quad \textbf{(Eq. 4)}$$

Note that the first part of the right side of (Eq. 4) corresponds to the general level of earnings in the economy and the second part corresponds to the individual's productivity. We assume that the first part is stochastic and the second part is deterministic. We model the $MTAWE_t$ using an economic

¹³ i.e., for example, if the total earnings of a 30 year old male in 2009 is 80% of the $MTAWE_{2009}$, then we assume that the total earnings of a 30 year old male in year t is also 80% of the $MTAWE_t$

scenario generator and more details of the model are given in Section 4. The second part of the (Eq. 4) requires knowledge of the age-earning profile for males. We estimate the age-earning profile for a given education level using a model of the form

$$\log[W(x)] = \beta_0 + \beta_1 y + \beta_2 y^2 + \varepsilon \quad \text{(Eq. 5)}$$

where, $W(x)$ is the median total annual earnings for an individual aged x , and y is the number of years of experience assuming that the person entered the workforce at age 20 (i.e. $y = x - 20$), ε is the error term of the regression, and the β 's are the parameters to be estimated.

Ideally age-earnings profiles should be estimated using longitudinal data for a specific birth cohort. However, such data is rarely available due to the costs involved in such studies, and thus in practice cross-sectional data is often used to estimate the age-earnings profiles. We estimate the model given in (Eq. 5) by using the ABS micro dataset - Survey of Education and Training 2009 (SET09). The SET09 is a national survey conducted between March and June 2009 which contains a range of cross-sectional micro data on employment status, sex, age, education level, and job industry. To calibrate the model we only considered the observations where the worker's age was between 20 and 67, working between 35 to 59 hours per week, where the principal source of income was employee income, the worker was not an owner of an incorporated enterprise, and had no disability or long-term health condition. Our assumption of full-time work may overstate the average joint income for couples where there may be a propensity to undertake part-time employment by one or both of the couple.

We considered several distributional assumptions for ε including Normal, Lognormal, and Gamma to estimate (Eq. 5). We found that the Normal distribution to be an appropriate distribution for the error term based on the AIC criterion as well as normalised quantile plots of Dunn and Smyth (1996). In other words, wages have a lognormal distribution. The estimated parameter values for individuals with an education level of an Advanced diploma¹⁴ using Normal errors are given in Table 3. The fitted curves are given in Figure 1.

¹⁴ According to our sample data the average income for individuals with Advanced diploma is close to the Average income of Australians. Therefore, education level of an Advanced diploma was used in the base case.

Using the estimated parameters we can compute estimates of $\widehat{AER}(x)_M$ for different ages x as

$$\widehat{AER}(x)_M = \frac{\exp\left(\hat{\beta}_0 + \hat{\beta}_1 y + \hat{\beta}_2 y^2 + \frac{\hat{\sigma}^2}{2}\right)}{MTAWE}$$

where, $\hat{\sigma}^2$ is the estimated standard deviation of $\varepsilon \sim N(0, \sigma^2)$ in (Eq. 5) and $MTAWE$ is the male total average weekly earnings for the reference period using the chosen sample of the SET09 data. Then together with the simulated values of $MTAWE_t$ from the economic scenario generator for time t and the estimated $\widehat{AER}(x)_M$ schedule, one can compute the total earning for a male with given age x in the future time t . The same method can be used to simulate the total earnings for females by estimating $\widehat{AER}(x)_F$ and simulating $FTAWE_t$ using the economic scenario generator.

The economic scenario generator needs to model the annual growth of $MTAWE$ and $FTAWE$ in order to simulate the general level of earning in the economy for males and females. However, we were only able to model the annual growth of male wages since earnings data was not available for female workers prior to 1983. Therefore, to model $FTAWE$ we made the assumption that the growth of female wages can be approximated by the growth of $MTAWE$. The approximation can be justified from the high correlation (around 0.8) between the growth of $FTAWE$ and the growth of $MTAWE$ in the past.

Contributions to super funds are made as a percentage of ordinary time earnings rather than the total earnings. Therefore, to determine superannuation account balances we need to know the ordinary time earnings of the individuals. This can be achieved by taking a percentage of total earning as

$$\text{ordinary time earnings at age } x = \alpha W(x) = \alpha \times (M/F)TAW E \times AER(x)$$

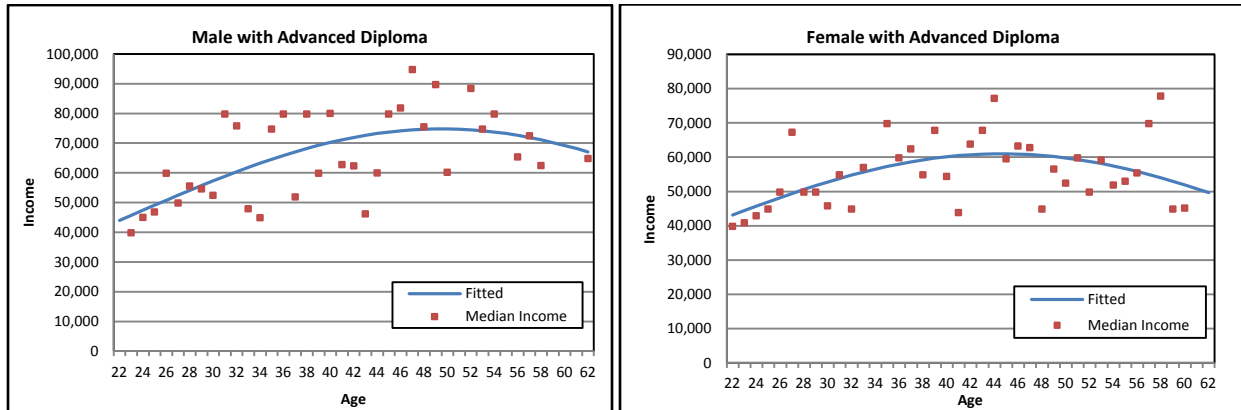
where α is the ratio between ordinary times earnings and total earnings from SET09. We found $\hat{\alpha} = 0.938$ for men and $\hat{\alpha} = 0.922$ for women.

Table 3: Parameter Estimates for the Age-Earnings Profiles

	Male		Female	
	Estimate	St. Error	Estimate	St. Error
β_0	10.5960	0.1140	10.5963	0.0751
β_1	0.0414	0.0121	0.0334	0.0085
β_2	-0.0007	0.0003	-0.0007	0.0002
σ	0.1825	0.0323	0.1504	0.0251
Adjusted R^2	0.38		0.31	

Note: The normalized quantile residuals of Dunn and Smyth (1996) for both males and females appeared to follow a standard normal distribution and had p -values of 0.77 and 0.21 respectively under Shapiro-Wilk test.

Figure 1: Fitted Age-Earning Profiles



3.4. Contributions to the Superannuation Fund

In the budget of 2010-11 the Australian Government proposed to gradually increase the SG rate from 9% to 12% by 2019. Taking into account this proposed change and our intention to consider a mature SG system, we have set the contribution rate in our study as 12%. We assumed employers make contributions of 3% of the employee’s annual ordinary time earnings to a superannuation fund every quarter as required by the law (Leow, Murphy, Hooper, & CCH Australia Limited., 2008, p. 727). We note that the increases in the SG rate have been deferred but this does not affect our analysis.

3.5. Taxes

Superannuation moneys are taxed at three points, when contributions are received by the superannuation fund, when the fund makes investment returns, and when benefits are paid to the member. The tax rates which apply depend on whether the fund complies with Government regulations or not. Most of the large superannuation funds comply with the Government regulations and therefore we used the tax rates which apply to complying funds in our simulations. For our simulations we consider contributions are taxed at 15% quarterly, which is the usual concessional tax rate for SG contributions received by a complying fund.

Investment returns on a complying fund are taxed at 15%, however, the effective tax rate is much less than 15% due to tax deductions available from dividend imputation, and foreign tax credits as well as the tax treatment of capital gains. Previous work has made different assumptions about the effective tax rate on investment returns. For example, Rothman (2003) assumed a 6.5% effective tax rate, Bateman (2006) assumed 8%, Rothman (2011) assumed 5%, and Gallagher (2011) assumed 7%. We have assumed a 7% effective tax rate which is used by the Treasury in their RIMHYPO model (Gallagher, 2011). The tax on investment earnings are assumed to be paid annually. The effective tax rate on investment returns will be affected by the asset mix adopted, but unless there is a dramatic difference in the exposure to shares in particular, the effective tax rate will not change much, and we have therefore used the same effective tax rate across all three types of investment funds that we have considered.

We need to make assumptions as to personal tax rates before and after retirement to determine the adequacy rates. To compute the disposable income during the final year of work we assumed the 2010-11 personal tax rates would continue into the future. The personal income tax rates for 2010-11 are given in Table 4. We assumed retirees did not pay taxes after retirement. This is justified since superannuation benefits are tax free if withdrawn after age 60 from a taxed fund¹⁵ and Age Pension payments are effectively tax free due to available tax offsets.

¹⁵ Complying funds are considered taxed funds. However, there are small number of public sector funds which are tax exempt due to constitutional restrictions of taxing public sector entities.

Table 4: 2010-11 Personal Tax Rates

Description	Tax Rate
<i>Income Taxes</i>	
0 - \$6,000	Nil
\$6,001 - \$37,000	15c for each \$1 over \$6,000
\$37,001 - \$80,000	\$4,650 plus 30c for each \$1 over \$37,000
\$80,001 - \$180,000	\$17,550 plus 37c for each \$1 over \$80,000
\$180,001 and over	\$54,550 plus 45c for each \$1 over \$180,000
<i>Other Taxes and Tax Offsets</i>	
Medicare Levy	1.5%
Low Income Offset	$Max[Min[(1500 - (Income - 30,000) \times 0.04), 1500], 0]$

3.6. Fees and Charges

A superannuation fund's fees and charges are an important determinant of the member's account balance. AustralianSuper disclosed on their website that for the 2012/2013 financial year, their investment fees ranged from 0.81% to 0.39% for diversified investment options¹⁶ and administration fees were \$1.50 per week¹⁷. As the majority of employees will have their SG contributions passed through funds similar to AustralianSuper we assumed a simplified fee structure consisting of \$19.50 adjusted for inflation and deducted quarterly, plus an investment management fee of 0.65%, also deducted quarterly.

3.7. Asset Allocation

The asset allocation assumed to be adopted by the member was chosen based on the investment options provided by a leading industry super fund. The set of asset allocations used are given in Table 5. We assumed cash was invested in Australian government bills, long term interest bearing securities were invested in Australian 10-year government bonds, domestic equities were invested in a fund which tracked the S&P/ASX 200 accumulation index, and international equities were invested in a fund which tracked the MSCI World ex AU total return index. In addition it is assumed that the portfolio is rebalanced every quarter and there are no costs in rebalancing the portfolio. For the base case scenario we assumed funds were invested in the balanced investment option, and then we tested the change in the results for each of the investment options given in Table 5.

¹⁶ <http://www.australiansuper.com/investments-and-performance/investment-fees.aspx>

¹⁷ <http://www.australiansuper.com/superannuation/what-we-offer/fees-and-costs.aspx>

Table 5: Asset Allocation

Investment Option	Cash	Long Term Interest bearing Securities	Domestic Equity	International Equity
Growth	3%	11%	54%	32%
Balanced	5%	25%	50%	20%
Stable	30%	35%	25%	10%
Age Phasing	First 14 years in Growth, the second 14 years in Balanced, and last 14 years in Stable			
Reverse Age Phasing	First 14 years in Stable, the second 14 years in Balanced, and last 14 years in Growth			

3.8. Management of Assets in Retirement

We assumed that the individuals buy a wage indexed life annuity at retirement, which transfers the investment, inflation and longevity risk to the issuer. For couples, we assumed the indexed life annuity they buy is a joint annuity with 65% of the benefit payable to the last survivor. The reversionary beneficiary feature of the joint annuity was set at 65% since the ratio between the Age Pension payments for singles and couples is close to 65%. Given the non-existence of a lifetime annuity market in Australia, we assumed an actuarially fair value price as given in (Eq. 6) and (Eq. 7).

$$P_{single} = \sum_{t=1}^{(\omega-67) \times 4} \frac{A_r (1+e)^t {}_{t/4}p_{67}^m}{(1+i)^t} \quad \text{(Eq. 6)}$$

$$P_{joint} = \sum_{t=1}^{(\omega-67) \times 4} \frac{A_r (1+e)^t {}_{t/4}P_{67}^m {}_{t/4}P_{67}^f + 0.65 A_r (1+e)^t [{}_{t/4}P_{67}^m (1 - {}_{t/4}P_{67}^f) + {}_{t/4}P_{67}^f (1 - {}_{t/4}P_{67}^m)]}{(1+i)^t} \quad \text{(Eq. 7)}$$

where, A_r denotes the quarterly real payouts from the annuity, ω is the maximum age a person is expected to live (assumed to be 110), e is the quarterly indexation based on the wage growth above inflation, ${}_{t/4}P_{67}^m$ is the probability of survival until age $(67 + \frac{t}{4})$ for a male who is aged 67 in 2052, ${}_{t/4}P_{67}^f$ is the probability of survival until age $(67 + \frac{t}{4})$ for a female who is aged 67 in 2052, and i is

the quarterly real yield on a 10-year government bond at the time of retirement as simulated by the econometric scenario generator (See Section 4).

In the past, the Australian Government has benchmarked the Age Pension by using the MTAWA. Consistently, we fix the quarterly indexation of the annuities at 0.335% which is the long-run growth of real wages.

The survival probabilities in (Eq. 6) and (Eq. 7) are cohort survival probability rates. The cohort survival probabilities were computed using period mortality rates given in the Australian Life Tables 2005–07 (AGA, 2009). In order to compute cohort survival probabilities one needs to age the period life tables up to 2052 (year of retirement), and then delineate by cohort using projected mortality improvements. In this study we have used the conservative 100-year mortality improvements for ageing the period tables and delineating the cohorts. A detailed explanation of how to compute cohort survival probabilities can be found in Ganegoda (2007).

It is worth pointing out that majority of Australian retirees take their superannuation benefit as a lump sum rather than buy an annuity as we have assumed here. In such instances the adequacy of the benefit will depend on various factors such as individual spending patterns, investment performance of the products invested in and longevity of the retiree. Given the complexity of modeling the interactions between such factors we did not consider lump sum retirement benefits in this study.

3.9. Age Pension

The Age Pension is an important source of income for most Australian retirees. At June 2008, around 68% of the Australians of eligible age received at least part of the Age Pension, with 56% receiving the full rate (ABS, 2009). Thus, it is important to take into account the Age Pension payments when analysing the adequacy of the retirement system. In order to receive the Age Pension there are requirements as to residency, age, assets and income. The current minimum age requirement is 65 for men and 62.5 for women and is set to gradually increase up to 67 for both men and women by 1st July 2023. The Age Pension payments are subject to both an income and an asset test. In practice, pension payments are paid fortnightly, however, for computational simplicity

we assumed Age Pension payments are payable and means tested quarterly. The amount of quarterly Age Pension payable under the income test is:

$$AP_{Inc_test} = Max[Min[(MAP - (Inc - T_{Inc}) \times 0.5), MAP], 0]$$

The amount of quarterly Age Pension payable under the asset test is:

$$AP_{Ast_test} = Max[Min[(MAP - (Asst - T_{Ast}) \times 0.00975), MAP], 0]$$

where, AP_{Inc_test} is the Age Pension payable under the income test, AP_{Ast_test} is the Age Pension payable under the asset test, MAP is the maximum quarterly Age Pension, Inc is the amount of assessable quarterly income, $Asst$ is the value of assessable assets, T_{Inc} is the quarterly income threshold, and T_{Ast} is the asset threshold. Whilst the ABS 2012 Survey of Wealth (ABS, 2012) indicated that the mean household held on average significant assets outside of superannuation, the distribution of non-superannuation assets is highly skewed with the bulk of the non-superannuation assets being held by very few households, so given our purpose is to just consider in this study the “typical” retiree earning AWOTE, to determine the assessable income and assets we assumed the only asset outside of superannuation was the owner-occupied house, which is exempted from the means test. Thus, the only assessable asset is the value of the annuity at purchase minus the capital which has already been paid out as given by (Eq. 8)

$$Assessable\ Asset = Purchase\ price - \frac{Purchase\ price}{Relevant\ number} \times \text{term elapsed} \quad \text{(Eq. 8)}$$

and the only assessable income is the income received from the life annuity after allowing for return of capital as given by (Eq. 9)

$$Assessable\ income = Annuity\ payment - \frac{Purchase\ price}{Relevant\ number} \quad \text{(Eq. 9)}$$

In (Eq. 8) and (Eq. 9) the Relevant Number is the life expectancy of the annuity owner and if a joint annuity then the longer life expectancy of the joint owners. We used Australian Life Tables 2005-2007 with the 100 year mortality improvement adjustments to determine the life expectancy. As at March 2011, the total Age Pension after combining the base rate and the pension supplement is equal to 29.36% of MTAWWE for singles and 44.27% of MTAWWE for couples. In order to determine the MAP we assumed that the current government policy of benchmarking Age Pension payments to MTAWWE would continue into the future. Thus, we set the MAP for singles equal to 29.36% and for couples 44.27% of the simulated value of the MTAWWE at the time of retirement. In practice the income and asset thresholds T_{Inc} and T_{Asst} are adjusted in line with the consumer price index, and

this would mean we would not need to change the threshold values since we are carrying out all the simulations in real values. However, since real wages tend to increase in the long run, then keeping the thresholds constant would mean less and less individuals would be eligible for the Age Pension as time goes by. To avoid this we assumed the current ratio between the thresholds and the MTAWWE remained the same into the future.

4. The Economic Scenario Generator

This Section presents the detailed methodology of the economic scenario generator used in this study. Firstly, we will outline some of the economic scenario generators found in the existing literature and then show why we believe the new semi-parametric economic scenario generator we developed is more appropriate for our purpose.

4.1. Existing Methods to Generate Economic Scenarios

Economic scenario generators are extensively used in actuarial and finance applications to model future economic scenarios. Methods to simulate economic scenarios can be broadly categorized into parametric and non-parametric models. Many different parametric and non-parametric models have been proposed by different authors depending on the need of the application.

One of the well-known and earliest parametric models found in the actuarial literature is the Wilkie model (Wilkie, 1986, 1995). Australian versions of the Wilkie model have been developed by Carter (1991) and Butt & Deng (2010). The Willkie model is a system of linear time series models based on a cascade structure. Usually inflation is considered as the main driving force of other variables and causality is assumed to be unidirectional. However, there is empirical evidence of feedback effects between certain economic variables and therefore the unidirectionality assumption of the Wilkie model can become problematic (see Sherris, Tedesco, & Zehnirith, 1999 for empirical evidence of feedback effects in Australian economic variables). Sherris and Zhang (2009) explored several alternative parametric models to generate economic scenarios for the Australian economy using 11 economic variables. First, the authors attempted to fit an Exponential Regressive Conditional Heteroscedasticity (ERCH) model as proposed by Harris (1994) to more recent Australian data. They were unable to find a satisfactory fit using an ERCH model and thus turned to three other

alternative models: a univariate regime switching model, a VAR model and a multivariate regime switching model. Univariate regime switching models performed well for most series. The VAR model performed reasonably well although the dynamics of some variables were not captured well due to inadequacy of the assumption that the log-returns of the series are normally distributed.

Non-parametric methods have also been used to simulate economic scenarios. One of the simplest non-parametric methods is to draw asset returns from an empirical return distribution with replacement. This approach assumes there is no serial correlation in returns. If values for more than one variable are needed then the simulation is carried out by randomly resampling from all the variables within the same historic time interval. This has the advantage of preserving contemporaneous correlation between variables. In the following sections we will refer to this method as raw bootstrapping. Applications of raw bootstrapping in pension fund analysis can be found in Poterba, Rauh et al. (2007) and Basu and Drew (2010). Alternatively it is possible to carry out stationary bootstrapping to account for serial correlation. An application of stationary bootstrapping to pension fund analysis can be found in Blake, Cairns et al. (2001).

Both parametric and bootstrapping methods have their advantages and disadvantages. If properly set up, parametric methods can provide superior results in capturing short-term and long-term dynamics of the variables. They can simulate scenarios yet to be observed in the future. However, the main drawback of parametric methods is that they are often based on questionable model assumptions. Furthermore, they carry the risk of model misspecification and parameter uncertainty. The bootstrapping methods have several advantages over parametric methods in that they are straight forward to implement and usually do not rely on questionable model assumptions as do parametric models. As well, it is much easier to capture the properties of empirical distribution functions and implicitly preserve the dynamic dependence structure between variables. However, the disadvantages of bootstrapping are that simulated values cannot take values other than the realised historical values, and long-run relationships might not be captured adequately.

To overcome the limitations of parametric and non-parametric approach we have used a semi-parametric economic scenario generator in this study.

4.2. A Semi-Parametric Economic Scenario Generator

The semi-parametric economic scenario generator used in this study has been adapted from Müller, Bürgi et al. (2004). The basic steps behind the model are as follows.

Consider a K number of time series variables $\mathbf{Y}_t = (y_{1,t}, y_{2,t}, \dots, y_{K,t})'$, where \mathbf{Y}_t is the vector of realized values at time $t = 1, 2, \dots, T$.

Model Fitting

- 1) Fit a parametric model to the time series data without making distributional assumptions about the variables.
- 2) Compute the expectation of the variables at time $t - 1$ for time t , denoted as $E_{t-1}(\mathbf{Y}_t)$, using the fitted parametric model.
- 3) Compute the raw innovation vectors $\hat{\mathbf{u}}_t^{raw} = \mathbf{Y}_t - E_{t-1}(\mathbf{Y}_t)$ for $t = 1, 2, \dots, T$
- 4) Compute the detrended innovation $\hat{\mathbf{u}}_t$ by using the (Eq. 10), in Section 4.2.2.

Simulating N time periods

- 5) Carry out a stationary bootstrap on the de trended innovation vector to simulate $\hat{\mathbf{u}}_{T+1}, \hat{\mathbf{u}}_{T+2}, \dots, \hat{\mathbf{u}}_{T+N}$, see Section 4.2.3.
- 6) Set $n = 1$
- 7) Compute the next period market expectation $E_{T+n-1}(\mathbf{Y}_{T+n})$ by **using the fitted parametric model**
- 8) Compute the simulated value $\mathbf{Y}_{T+n} = E_{T+n-1}(\mathbf{Y}_{T+n}) + \hat{\mathbf{u}}_{T+n}$
- 9) Set $n = n + 1$
- 10) If $n \leq N$ go to step 7 or else stop.

4.2.1. The Choice of Parametric Model

The choice of the parametric model in step 1 plays an important role in the semi-parametric algorithm. A good model should be simple and parsimonious but still be able capture the stylized facts observed in the time series data. In addition, when choosing a model one should take into account the nature of the application and the time-horizon of the simulation exercise. For example, models which provide the best short-term forecasts might not capture the long-run dynamics between the variables and may not be suitable for applications with long time horizons. As Wilkie (1995) points out, for the purpose of short-term forecasts, models with minimum short-term errors are appropriate, whereas for long-term simulations models which adequately capture the variance structure are more suitable.

Based on the findings of the previous studies we chose a Vector Error Correction Model (VECM) for the parametric part of the algorithm to calculate the expected value $E_{T+n-1}(\mathbf{Y}_{T+n})$. There are several reasons for choosing a VECM framework. A VECM is a restricted VAR model and therefore each variable is modeled using its own previous values and the previous values of all the other variables in the system. This has the advantage of capturing two stylized facts observed in economic time series. First, including its own values to predict a variable captures the often observed serial correlation in economic variables. Second, including previous values of other variables in the regression equation captures the feedback effects between variables. Another advantage of the VECM framework is that it can explicitly model the long-run relationships between the variables by co integration analysis. Modeling such long-run relationships are important for simulation studies with long time horizons since there is evidence that in the long-run certain economic variables such as interest rates tend to move together. Not properly accounting for the long-run relationships can create serious distortions in the simulated results.

Since we do not make explicit assumptions about the underlying distribution of the variables, we use the two-step (S2S) estimation procedure based on the feasible generalised least squares (EGLS) method as described in Brüggemann and Lütkepohl (2005) to estimate the parameters of the VECM. More details about the calibration of the economic scenario generator and the estimated parameters can be found in the Appendix. A theoretical exposition on the VECM framework and a detailed discussion about the semi-parametric econometric generator can be found in Ganegoda (2012).

4.2.2. Detrending Innovations

The simulation algorithm assumes that the innovations $u_{i,t}$ for $i = 1, 2, \dots, K$ have an expected value of zero. In other words, ideally the mean of $\hat{u}_{i,t}$ should be zero. However, it is possible that the empirical mean may slightly deviate from zero. This has the risk of introducing a trend in the simulated results. Therefore, Müller, Bürgi et al. (2004) recommends de-trending the innovations using (Eq. 10) provided mean of $\hat{u}_{i,t}$ is close to zero.

$$\hat{u}_{i,t} = \sqrt{\hat{u}_{i,t}^{raw} \frac{T}{T-1} \left(\hat{u}_{i,t}^{raw} - \frac{1}{T} \sum_{t=1}^T \right)} \quad (\text{Eq. 10})$$

4.2.3. Stationary Bootstrapping

In step 5 of the algorithm, bootstrapping is carried out by using stationary bootstrapping instead of raw bootstrapping as proposed by Müller, Bürgi et al. (2004). In order to perform a raw bootstrap, the innovation series should be i.i.d. For most economic time series this assumption would be violated due to volatility clustering. As a response Müller, Bürgi et al. (2004) proposed to standardize the innovations by using Generalized Autoregressive Conditional Heteroskedasticity (GARCH) filters, then bootstrap the standardized innovations, and finally reintroduce the GARCH effects by multiplying the bootstrapped standardized innovations by a standard deviation process computed from the fitted GARCH model. Though theoretically a sound solution, we found that use of GARCH filters grossly overestimated the tails of the distribution for certain variables. The reason for this is the difficulty in estimating a GARCH model when the amount of data is limited. By using a robust maximization algorithm Zumbach (2000) reported that even for data generated by a GARCH(1,1) process they could not find meaningful parameter estimates 24% of the time for samples with 125 observations, and 7% of the time for samples with 250 observations. Similar findings have been reported by Bellini and Bottolo (2008). Furthermore, Bellini and Bottolo (2008) report that the problem is exacerbated when there is uncertainty as to which GARCH specification to use. In particular, they found that GARCH models tend to overestimate the variance if the underlying innovations have fatter tails than the distribution specified under the GARCH model. Fitting GARCH models to long periods raises further issues due to non-stationary behavior of the variance of most financial series in the long-run. Standard GARCH models assume variance is a stationary process, but for long time periods the variance process may behave like a non-stationary process. One possibility to model such behavior is to use an Integrated GARCH model. However,

Mikosch and Stărică (2004) point out that distinguishing whether a series is actually non-stationary or stationary is quite difficult, and therefore increases the risk of model misspecification. Given that we only have 165 quarterly observations, we decided not to use GARCH filters to standardize the innovations. Instead we introduced a stationary bootstrapping step, a method developed by Politis and Romano (1994). Stationary bootstrapping is a resampling method which can approximate any stationary weakly dependent time series. In contrast to raw bootstrapping, the pseudo-time series generated by the stationary bootstrapping are also stationary given that the original series is stationary. Therefore, stationary weakly dependent processes such as GARCH processes can be approximated non parametrically by using the stationary bootstrap method.

4.2.4. Seasonality

Certain economic time series variables exhibit deterministic seasonal variation. In such instances the long run average of the variable for a particular season is significantly different from the long run average for other seasons. Müller, Bürgi et al (2004) point out that if a time series contains a seasonal component then bootstrapping cannot be applied directly because it is unsuitable to use the innovations of one season to simulate another. Since seasonality is a cyclic predictable movement, we account for seasonality by including centered seasonal dummy variables in the VECM.

4.2.5. Market Crashes

From time to time large market crashes wipe out billions of dollars of wealth. A recent example of a global scale market crash is the GFC of 2008. Such market shocks can have significant impact on superannuation fund account balances and in turn can seriously impair the retirement income adequacy. The effect would be significant if the crash occurred just a few years prior to retirement since the account would not have enough time to recover from the losses. The implication of such an event for employees would be that they would need to either postpone their retirement, or reduce their standard of living in retirement. Thus, it is vital to take into account the possibility of market crashes when assessing the adequacy of the retirement system. Surprisingly, previous research has paid little attention to the adequacy of SG system under market crashes. Modeling market crashes is extremely difficult and falls outside the realm of Knightian risk. Conventional statistical methods have found little success in modeling the erratic behavior of markets and therefore academics have turned to other tools such as behavioral finance, chaos theory, Elliott

wave principles, and Complexity Theory to model the erratic behavior of markets. However, the science of bubble formation and bursts still remains largely unsolved, and given these circumstances, a natural way to incorporate the Knightian uncertainty of market crashes in our analysis is to externally include various scenarios of market crashes into the Monte Carlo steps.

We considered the seven historical market shocks given in Table 6 that occurred during 1970 to 2010 as possible future shock scenarios. Given that there were seven major market shocks during the past 40 years that had significant impact on the Australian economy, we assumed that on average a person with a 42-year work-life would experience seven market shocks during the accumulation stage of their superannuation. Based on this assumption we considered the following four scenarios in our analysis: no shocks, five shocks, seven shocks, and nine shocks. For simplicity, we assumed that the number of market shocks is known in advance but the timing is unknown. We further assumed a shock could occur during any quarter of the simulation period with equal probability. Note that not all shocks are of same length. A shock can last for a minimum of one quarter to a maximum of seven quarters. Given that there are M number of market shocks during the simulation period, the simulation algorithm can be altered as follows to incorporate market shocks:

Simulation of N Years

- 5) carry out a stationary bootstrap on the de trended innovation vector to simulate $\hat{\mathbf{u}}_{T+1}, \hat{\mathbf{u}}_{T+2}, \dots, \hat{\mathbf{u}}_{T+N}$
- 6) randomly draw M number of shocks from Table 6 such that shocks will not overlap each other. A randomly drawn shock is denoted as $(\mathbf{R}_{m,1}, \mathbf{R}_{m,2}, \dots, \mathbf{R}_{m,d_m})$ where $\mathbf{R}_{m,j}$ is the vector containing the quarterly returns of all the variables of interest for the j^{th} quarter of the m^{th} shock and d_m is the duration of the m^{th} shock in quarters. The set of randomly drawn shocks can be represented as $\{(\mathbf{R}_{1,1}, \mathbf{R}_{1,2}, \dots, \mathbf{R}_{1,d_1}), \dots, (\mathbf{R}_{M,1}, \dots, \mathbf{R}_{M,d_M})\}$. The timing of the shocks are denoted as $\{t_1^*, \dots, t_M^*\}$.
- 7) set $n = 1$, and $m = 1$
- 8) if $T + n = t_m^*$ else go to step 9
 - 8.1) set $j = 1$
 - 8.2) compute $\mathbf{Y}_{T+n} = (1 + \mathbf{R}_{m,j}) \circ \mathbf{Y}_{T+n-1}$,
 - 8.3) If $(j < d_m \text{ and } n < N)$ else go to sep 8.4
 - 8.3.1) set $n = n + 1$, and $j = j + 1$,
 - 8.3.2) go to step 8.2
 - 8.4) else
 - 8.4.1) set $n = n + 1$, and $m = m + 1$
 - 8.4.2) if $n \leq N$ go to step 8, or else stop
- 9) else (that is if $T + n \neq t_m^*$)
 - 9.1) compute the market expectation $E_{T+n-1}(\mathbf{Y}_{T+n})$ using the fitted parametric model.
 - 9.2) compute the simulated value $\mathbf{Y}_{T+n} = E_{T+n-1}(\mathbf{Y}_{T+n}) + \hat{\mathbf{u}}_{T+n}$
 - 9.3) set $n = n + 1$
 - 9.4) if $n \leq N$ go to step 8, or else stop

Note: \circ is the entry wise product

Table 6: Historical Financial Market Shocks

Scenario	Period	Duration in Quarters	Nominal Return	Description
1	Jan-73 to Sep-74	7	ASX: - 50.9% MSCI: -40.8% BND: -11.8% CASH: 13%	The 1973–1974 market crash which affected all the major stock markets in the world. The crash came after the collapse of the Bretton Woods system and was exacerbated with the 1973 oil crisis.
2	Jul-81 to Sep-81	1	ASX: - 16.8% MSCI: -10.0% BND: -6.9% CASH: 3.5%	One of the shocks during double dip recession of the early 1980s
3	Jan-82 to Mar-82	1	ASX: - 2.5% MSCI: -21.4% BND: 3.0% CASH: 4.2%	One of the shocks during double dip recession of the early 1980s
4	Oct-87 to Dec-87	1	ASX: - 40.7% MSCI: -16.3% BND: 1.3% CASH: 2.6%	The well known “Black Monday” which occurred in 19 th Oct 1987. Some of the reasons attributed to crash includes program trading, monetary policy disputes between the G7 countries, and market psychology.
5	Jan-90 to Dec-90	4	ASX: - 14.6% MSCI: -17.5% BND: 19.7% CASH: 15.1%	The savings and loans crisis in US forced countries which had close economic ties with US to fall into recession in the early 1990s. Australia was officially declared to be in recession on 29 th Nov 1990.
6	Apr-02 to Sep-02	2	ASX: - 27.2% MSCI: -11.3% BND: 11.8% CASH: 2.5%	The burst of the dot-com bubble. The bubble started in around 1995 due to rapid growth in internet related stocks.
7	Jan-08 to Dec-08	4	ASX: - 24.5% MSCI: -38.4% BND: 26.3% CASH: 6.9%	Global financial crisis which is considered the worst financial crisis since great depression. Number of factors have been attributed to the crash including, poor and fraudulent subprime lending practices, incorrect pricing of credit derivatives, housing bubble, over-leveraging etc.

Note: Details of the market indices can be found in the Appendix.

5. Results

5.1. The Results for the Base Case

Table 7 shows the likely distribution of replacement rates from the Australian superannuation system for cohorts of retirees with the same experience as to salary and investment return volatility. The percentiles which do not meet the adequacy requirements are highlighted in grey. The results indicate that the probability of the replacement rate falling below the target rate for a male from a cohort who experienced nine market shocks is 48%, whereas for a male from a cohort who experienced no market shock it is only 8%. The results further indicate that whilst some cohorts may enjoy replacement ratios of 427%, others can be expected to enjoy a 46% replacement ratio, i.e. for some cohorts, their retirement disposable income will be more than four times their pre-retirement disposable income, whilst other cohorts may only receive less than half of their pre-retirement disposable income. The replacement rates and the probability of achieving adequacy targets significantly improve if a particular cohort is fortunate enough to miss one or two market shocks. The expected replacement rates show a similar range for married couples. The results arising from capital market shocks, which are a “lottery” so far as contributors are concerned and are uncontrollable, indicate that the Australian retirement system will not deliver anywhere near similar retirement standards of living for various cohorts. Furthermore we have assumed full time employment for both the male and female in the base case for couples. Hence, the results stated here will be overstating the replacement rates for many couples where one of the couple is not working or in part-time employment.

It needs to be borne in mind our analysis assumes the retirees buy an annuity, so fluctuations in incomes after retirement do not occur, and had we assumed the retirees continued to invest their own funds with exposure to capital market volatility, the results would have been far more dispersed. Our findings suggest that there is a significant risk of the post-retirement standard of living being lower than the pre-retirement standard of living for couples as well as for single males, with the risk being higher for couples than for single males. The two main reasons for this are, firstly, the amount of Age Pension couples receive is not twice what single individuals receive, and secondly, a couple's joint annuity is more expensive than the single life annuity due to the reversionary beneficiary feature (which reduces the retirement income for couples).

Although married couples face a higher risk of falling below the target replacement rates than single males, this does not necessarily mean couples are worse off at retirement. Budget ratios in Table 8 show that couples have higher probabilities of achieving a comfortable standard of living than single males. For example, for cohorts who experienced seven market shocks, the probability of not being able to afford a comfortable standard of living for a single male is 70%, whereas for a married couple it is only 62%. The reduction in living costs due to sharing is the main reason why couples have a higher probability of being able to afford a comfortable standard of living than single males.

Table 7: Distribution of Replacement Rates

Percentile	Single Male				Married Couple			
	No Shocks	Five Random Shocks	Seven Random Shocks	Nine Random Shocks	No Shocks	Five Random Shocks	Seven Random Shocks	Nine Random Shocks
5%	56%	49%	47%	46%	45%	38%	38%	38%
10%	65%	53%	51%	49%	54%	42%	41%	40%
15%	73%	56%	54%	52%	63%	45%	43%	42%
20%	82%	59%	56%	53%	72%	47%	45%	43%
25%	89%	61%	58%	55%	80%	49%	47%	45%
30%	97%	64%	60%	57%	89%	52%	48%	46%
35%	106%	66%	62%	58%	98%	54%	50%	48%
40%	116%	69%	64%	60%	107%	57%	52%	49%
45%	126%	72%	66%	61%	116%	60%	54%	50%
50%	137%	75%	68%	63%	127%	63%	56%	52%
55%	148%	79%	70%	65%	138%	67%	59%	54%
60%	162%	83%	73%	67%	152%	71%	61%	56%
65%	177%	88%	76%	70%	167%	76%	64%	58%
70%	195%	94%	80%	72%	183%	83%	68%	60%
75%	215%	102%	84%	75%	203%	92%	73%	63%
80%	243%	112%	91%	80%	229%	102%	79%	67%
85%	278%	125%	100%	85%	264%	116%	89%	73%
90%	332%	149%	114%	93%	316%	140%	105%	82%
95%	427%	193%	145%	110%	411%	184%	137%	100%
Mean	176%	92%	78%	69%	165%	81%	67%	58%
St. Dev.	142%	55%	38%	24%	138%	55%	39%	24%

Table 8: Distribution of Budget Ratios

Percentile	Single Male				Married Couple			
	No Shocks	Five Random Shocks	Seven Random Shocks	Nine Random Shocks	No Shocks	Five Random Shocks	Seven Random Shocks	Nine Random Shocks
5%	0.69	0.61	0.58	0.56	0.72	0.61	0.60	0.60
10%	0.80	0.66	0.63	0.60	0.87	0.67	0.65	0.64
15%	0.90	0.69	0.66	0.64	1.00	0.71	0.68	0.67
20%	1.00	0.72	0.69	0.66	1.14	0.75	0.71	0.69
25%	1.10	0.76	0.71	0.68	1.27	0.78	0.74	0.71
30%	1.20	0.79	0.74	0.70	1.41	0.83	0.77	0.74
35%	1.31	0.82	0.76	0.72	1.55	0.86	0.80	0.76
40%	1.43	0.85	0.79	0.74	1.70	0.90	0.82	0.78
45%	1.55	0.89	0.81	0.76	1.85	0.95	0.86	0.80
50%	1.68	0.93	0.84	0.78	2.02	1.00	0.89	0.83
55%	1.83	0.97	0.87	0.80	2.20	1.07	0.93	0.85
60%	2.00	1.02	0.90	0.83	2.41	1.13	0.97	0.88
65%	2.19	1.08	0.94	0.86	2.65	1.22	1.02	0.92
70%	2.41	1.16	0.99	0.89	2.92	1.33	1.08	0.96
75%	2.66	1.25	1.04	0.93	3.23	1.45	1.16	1.01
80%	3.00	1.38	1.12	0.98	3.64	1.63	1.26	1.07
85%	3.43	1.54	1.23	1.05	4.19	1.86	1.42	1.16
90%	4.10	1.84	1.40	1.15	5.03	2.23	1.66	1.30
95%	5.29	2.39	1.79	1.35	6.54	2.93	2.18	1.58
Mean	2.18	1.13	0.97	0.85	2.62	1.28	1.07	0.93
St. Dev.	1.75	0.68	0.47	0.30	2.20	0.87	0.61	0.38

5.2. Impact of Asset Allocation

In order to quantify the impact of asset allocation strategies on retirement income adequacy we carried out simulations using the following nine asset allocation scenarios whilst keeping all other assumptions the same as in the base case:

- 1) Single male – High Growth portfolio
- 2) Single male – Stable portfolio
- 3) Single male – Age Phasing portfolio
- 4) Single male – Reverse Age Phasing portfolio
- 5) Couple – High Growth portfolio
- 6) Couple – Stable portfolio
- 7) Couple – Age Phasing portfolio
- 8) Couple – Reverse Age Phasing portfolio
- 9) Couple – male with High Growth Portfolio and female with Stable portfolio

The analysis using different portfolios will indicate whether the impact of market crashes could be significantly reduced with reductions in the exposure to equities. The replacement rates for a couple under the nine asset allocation strategies, for a scenario of seven market shocks, are given in Table 9. The results show that the left tail of the distribution of replacement rates for each asset allocation strategy are almost identical. The reason behind this is the Age Pension, which offsets any reduction in retirement income from poor investment performances. Therefore, the results show that the replacement rate is predominately affected by the exposure to uncontrollable market crashes and asset allocation adopted does not have much effect.

The results indicate that individuals are better off investing in high risk asset allocation strategies such as high growth or reverse age phasing, since they can reap the benefit of potential higher gains while essentially sharing the downside risk with the government through the Age Pension. However, it should be noted that the results presented here only hold for an individual on an average salary. For individuals who earn more than the average, the results will be different, as they are unlikely to be eligible for the Age Pension that provides the safety net in our simulations.

Table 9: Replacement Rates for a Married Couple under Different Asset Allocation Strategies with Seven Market Shocks

Percentile	High Growth	Balanced	Stable	Age Phasing	Reverse Age Phasing	High Growth (male)/ Stable (female)
5%	38%	38%	38%	38%	38%	38%
10%	41%	41%	41%	41%	41%	41%
15%	43%	43%	43%	43%	43%	43%
20%	44%	45%	45%	45%	44%	45%
25%	46%	47%	47%	47%	46%	47%
30%	48%	48%	49%	49%	48%	48%
35%	49%	50%	51%	50%	50%	50%
40%	51%	52%	52%	52%	51%	52%
45%	53%	54%	54%	54%	53%	54%
50%	55%	56%	56%	56%	55%	56%
55%	57%	59%	58%	58%	58%	58%
60%	60%	61%	61%	60%	61%	60%
65%	63%	64%	64%	63%	64%	63%
70%	66%	68%	67%	67%	68%	67%
75%	71%	73%	70%	70%	72%	71%
80%	77%	79%	75%	76%	79%	77%
85%	88%	89%	82%	83%	89%	85%
90%	106%	105%	93%	96%	107%	99%
95%	141%	137%	112%	120%	143%	126%
Mean	67%	67%	63%	64%	68%	65%
St. Dev.	44%	39%	27%	31%	42%	35%

5.3. Impact of Career Breaks

Most married women will not work full-time for 42 years as we have assumed in the base case. They tend to work part-time as well as spend a considerable amount of time out of the workforce due to family commitments. A survey carried out by the Australian Institute of Superannuation Trustees (2011) found that four out of every five women took a career break, with the average break lasting 12 years. Such long career breaks can have serious implications in terms of retirement savings. To quantify the effect of long career breaks, we considered a couple where the female partner leaves the workforce at age 30 to have children¹⁸, stays out of the workforce for 12 years, and re-enters the workforce at age 42.

The replacement rates and the budget ratios for the stated scenario (and keeping all other assumptions the same as in the base case) are given in Table 11. As expected, replacement rates are lower than for the base case. We find that inclusion of a 12-year career break for the female partner increases the probability of the replacement rate and the budget ratio falling below the target level for the couple by around 6 to 8 percentage points compared to the base case.

¹⁸ In 2010, the average age of a mother at the birth of the first child was around 30 years (ABS, 2010a)

Table 10: Replacement Rates and the Budget Ratios for Disrupted Workforce Participation of the Female Partner

Percentile	Replacement Rates				Budget Ratios			
	No Shocks	Five Random Shocks	Seven Random Shocks	Nine Random Shocks	No Shocks	Five Random Shocks	Seven Random Shocks	Nine Random Shocks
5%	41%	38%	38%	38%	0.66	0.61	0.61	0.60
10%	48%	41%	41%	40%	0.77	0.66	0.65	0.64
15%	55%	44%	43%	42%	0.87	0.69	0.68	0.66
20%	61%	46%	44%	43%	0.96	0.73	0.70	0.68
25%	66%	48%	46%	44%	1.05	0.76	0.73	0.70
30%	73%	50%	47%	46%	1.16	0.79	0.75	0.73
35%	80%	52%	49%	47%	1.27	0.82	0.78	0.75
40%	87%	54%	50%	48%	1.38	0.85	0.80	0.76
45%	94%	56%	52%	49%	1.50	0.89	0.83	0.78
50%	102%	58%	54%	51%	1.63	0.93	0.85	0.81
55%	111%	61%	56%	52%	1.76	0.97	0.88	0.83
60%	121%	64%	58%	54%	1.93	1.02	0.92	0.85
65%	133%	68%	60%	56%	2.12	1.08	0.96	0.88
70%	147%	73%	63%	58%	2.33	1.15	1.00	0.92
75%	161%	79%	66%	60%	2.57	1.25	1.06	0.96
80%	182%	86%	71%	63%	2.88	1.37	1.13	1.00
85%	210%	97%	78%	68%	3.33	1.53	1.24	1.08
90%	250%	114%	89%	74%	3.97	1.81	1.41	1.18
95%	322%	149%	111%	86%	5.14	2.37	1.76	1.37
Mean	132%	71%	61%	55%	2.10	1.13	0.98	0.88
St. Dev.	106%	41%	29%	19%	1.69	0.65	0.46	0.30

6. Conclusion

Australia has a three-pillar retirement system consisting of a public pay-as-you-go Age Pension, an employment related mandated superannuation guarantee contribution accumulation (the SG system), and voluntary savings. The previous work to analyse the suitability of the retirement system has been mostly based on deterministic models. Very little effort has been made to quantify the risk associated with retirement income adequacy due to market uncertainty, and we are not aware of papers that consider the implications of the retirement system in terms of very different outcomes for various cohorts of retirees, primarily driven by capital market crashes. The main contribution of our study is to extend the previous literature to quantify a full probability distribution of replacement rates and budget ratios so that a comprehensive synopsis of the risks and the uncertainties of investing for retirement is obtained, together with its implications for effectively a "lottery" result for retirees.

In order to quantify the probability distribution of the replacement rates we simulated a range of possible retirement outcomes under various market conditions generated by an economic scenario generator. The economic scenario generator we developed for the analysis is a semi-parametric one which can simulate six economic variables. The long-run relationships between the economic variables were explicitly built into the model by the use of co integration relationships. The serial correlation of the economic variables was taken into account as well as lagged variables, and the dynamic contemporaneous dependence structure was preserved by using a bootstrap simulation technique for the innovations. The generator was calibrated using 40 years of historic data and was verified using several statistical tests as well as comparing simulated returns against the historic returns. Special emphasis was given to possible future market crashes. We incorporated the Knightian uncertainty arising from such events into our analysis by integrating market shock scenarios to the Monte Carlo steps of the economic scenario generator. A range of historic market shocks were used as the shock scenarios for simulation in order to obtain realistic market shocks which reflected the correlation between variables during stressed market conditions.

We observe that the probability of achieving adequate retirement standards can vary significantly depending on the number of market crashes that may happen during the investment period. This variation is attributable to the Knightian uncertainty of superannuation investments arising from the difficulty in modelling the severity and the timing of future market crashes. The results indicate that changing the asset allocation will not assist significantly to improve the probability of achieving the adequacy standards for a typical Australian worker. Whilst we have considered the effect of retirees having been out of employment, our model does not take into account part time employment, which would also impact the adequacy of the SG system, and this effect would be a worthwhile extension of our work.

There is a need for solutions to be considered in order to reduce the replacement risk faced by future retirees. A one possible solution may be to use portfolio insurance based on option strategies. Another would be to provide a minimum benefit guarantee based on a formula which takes into account factors such as the contribution rate, and the number of years of contribution.

All in all we believe our study has increased the understanding of risks and uncertainties involved with the SG system, and its potential unfairness. The results of the study have contributed to enhance the understanding of the likelihood of current SG system together with the Age Pension

delivering an adequate income support for Australians in retirement. Our analysis have taken to account both the Knightian risk as well as the Knightian uncertainty involved with the long-term nature of the superannuation investments. Hence, the results presented in this study paint a much more vivid picture of the possible future states of the retirement savings outcome. We believe the results of this study will provide better information for policy makers to understand the risks and uncertainties involved with the current SG arrangement, and therefore assist them to make better financial decisions.

Our analysis makes it clear that the Australian retirement system may not deliver the expected results for all Australians, and may create social unrest when the uncertainty and resulting unfairness of the system is realised.

7. Appendix: Calibration of the Econometric Model

We used six economic time series variables with quarterly data from the fourth quarter of 1969 to the fourth quarter of 2010, to calibrate the econometric model. Table 11 gives the time series variables and their source. All the time series variables are in real terms. Inflation adjustments were carried out using the Australian consumer price index published by The Australian Bureau of Statistics.

Furthermore, we adjusted the returns of the periods that includes the 7 shocks in Table 6 by multiplying by an appropriate constant such that the standard deviation of the individual series after adjustment matches the standard deviation of that series excluding the 7 shocks. By doing so we were able to avoid the double counting of market shocks during the simulation and at the same time preserve the properties related to short-run dynamics and long-run equilibrium of the time series.

Table 11: The Time Series Variables used in the Economic Scenario Generator

Symbol	Time Series Variable	Source / Mnemonic
CASH	Logarithm of inflation adjusted Australia total return bills index	Global Financial Data - TRAUSBIM
BND	Logarithm of inflation adjusted Australia 10-year government bond return index	Global Financial Data - TRAUSGVM
ASX	Logarithm of inflation adjusted Australia S&P/ASX 200 accumulation index	Global Financial Data - AXJOAD
MSCI	Logarithm of inflation adjusted MSCI World ex AU total return index in Australian dollars (i.e., unhedged).	Datastream - MSWXAU\$(RI)~A\$
BInd	Logarithm of CBI_t , which is a custom-made index designed to track the inflation adjusted Australian 10-year government bond yield such that $CBI_t = (1 + BYield_t)CBI_{t-1}$ where $BYield_t$ is the real return on Australian 10-year government bonds.	Global Financial Data - IGAUS10D
WInf	Logarithm of inflation adjusted average male earnings.	Datastream - 100611012

The first step in calibration of the econometric model is to fit an appropriate parametric model. This requires the knowledge of the order of integration for each time series variables and the presence of any long-run equilibriums. Thus, we performed Augmented Dickey Fuller (ADF) unit root tests and Saikkonen & Lutkepohl (S&L) co integration tests on the data. The ADF tests showed that all the series are I(1) processes and the S&L test showed that they are co integrated in the order of one. Therefore, we fitted a VECM to capture the short-run dynamics and long-run equilibrium conditions using the two-step (S2S) estimation procedure described in Brüggemann and Lütkepohl (2005). The final model takes the form

$$\Delta Y_t = \alpha \beta^T Y_{t-1} + \Gamma_1 \Delta Y_{t-1} + \mathbf{C} \mathbf{D}_t^{out} + \mathbf{u}_t$$

where, $Y_t = (BND_t, BInd_t, ASX_t, MSC1_t, WInft_t, CASH_t)^T$ and $\mathbf{D}_t^{out} = (1, CSD_{1,t}, CSD_{2,t}, CSD_{3,t})^T$ with $CSD_{i,t}$ being a centered seasonal dummy indicating the i^{th} quarter. The parameter estimates are

$$\hat{\alpha} = \begin{vmatrix} -0.2376 \\ 0 \\ 0 \\ 0 \\ 0.0034 \\ -0.0090 \end{vmatrix} \quad \hat{\beta} = \begin{vmatrix} 1 \\ -0.4233 \\ 0.1998 \\ -0.1100 \\ 0.3666 \\ -0.2222 \end{vmatrix} \quad \hat{\mathbf{C}} = \begin{vmatrix} 0.2434 & 0 & 0 & 0 \\ 0.0078 & 0.0080 & 0 & 0 \\ 0.0315 & 0 & 0 & 0 \\ 0.0101 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0.0110 & 0.0021 & 0 & 0 \end{vmatrix}$$

$$\hat{\Gamma}_1 = \begin{vmatrix} 0.2090 & 0.5096 & 0 & 0 & 0 & -1.5143 \\ 0.0862 & 0.7380 & 0 & 0 & -0.2989 & 0 \\ 0 & 0 & 0 & 0 & -1.6967 & 0 \\ 0 & 0.3462 & 0 & 0 & -1.0460 & 0 \\ 0 & 0.0834 & 0 & -0.0185 & 0 & -0.4313 \\ 0.0131 & 0 & 0 & 0 & -0.0879 & 0.7375 \end{vmatrix}$$

It is worth pointing out here that the residual series is used in the subsequent simulations as explained in Section 4. Since stationary bootstrapping is used for this purpose, we only need the residuals to be stationary. Therefore, as a test of goodness-of-fit of the fitted VECM, we tested the residuals series of the model for stationarity. The results presented in Table 12 show that ADF tests rejected the presence of unit roots and the Ljung–Box tests could not reject the null hypothesis of independence for the all the series.

Table 12: Tests for Stationarity of the Residuals

	BND	BInd	ASX	MSCI	CASH	Winf
Test Statistic of ADF test	-5.97	-11.13	-9.09	-6.09	-12.01	-5.73
P-value of Ljung-Box test	0.45	0.70	0.20	0.26	0.36	0.99

Note: critical values of ADF test at 95% is -1.95 and 99% is -2.58.

Table 13 provides a comparison between the simulated returns using the semi-parametric econometric model and the historical returns (after adjusting for the 7 shocks) as a further validation of the model.

Table 13: Comparison Between the Simulated Returns and the Historical Returns

Statistic		CASH	BND	ASX	MSCI	BYield	Winf
Mean	Historical	0.62%	0.93%	2.90%	1.94%	2.97%	0.30%
	Simulated	0.67%	1.05%	2.97%	1.99%	3.08%	0.28%
St. Dev.	Historical	0.87%	3.82%	7.22%	7.07%	3.17%	1.06%
	Simulated	0.80%	3.73%	7.18%	7.03%	2.98%	1.05%
25th Percentile	Historical	0.15%	-1.28%	-2.10%	-2.72%	0.90%	-0.34%
	Simulated	0.16%	-1.42%	-2.12%	-2.67%	1.05%	-0.38%
Median	Historical	0.67%	0.50%	2.80%	0.90%	2.70%	0.25%
	Simulated	0.65%	0.99%	2.78%	1.21%	2.89%	0.25%
75th Percentile	Historical	1.16%	3.32%	6.91%	6.42%	4.93%	0.83%
	Simulated	1.16%	3.46%	7.17%	6.32%	4.92%	0.89%

Note: Historical returns have been computed using the series after adjusting for the seven market shocks.

8. References

- Access Economics. (2009). The AMP Retirement Adequacy Report, Jan–Jun 2009
- AMP. (2009). AMP Retirement Adequacy Index, July - Dec 2009.
- Association of Superannuation Funds of Australia. (2011). The ASFA Retirement Standard, June 2011.
- Australian Bureau of Statistics. (2009). 4102.0 - Australian Social Trends, March 2009.
- Australian Bureau of Statistics. (2010a). 3301.0 - Births, Australia, 2010.
- Australian Bureau of Statistics. (2010b). 6291.0.55.001 - Labour Force, Australia, Detailed - Electronic Delivery, Dec 2010 (Table 14A. Unemployed persons by Duration of unemployment and Sex).
- Australian Bureau of Statistics. (2012). 6554.0 - Household Wealth and Wealth Distribution.
- Australian Government Actuary. (2009). Australian Life Tables 2005-07
- Australian Government Treasury, & Henry, K. (2009). Australia's Future Tax System - The retirement income system: Report on strategic issues.
- Basu, A. K., & Drew, M. E. (2010). The appropriateness of default investment options in defined contribution plans: Australian evidence. [doi: DOI: 10.1016/j.pacfin.2010.02.001]. *Pacific-Basin Finance Journal*, 18(3), 290-305.
- Bateman, H. (2006). *Labour Market Uncertainty and the Adequacy of the Superannuation Guarantee*. CPS Discussion Paper. Centre for Pensions and Superannuation, University of New South Wales. Retrieved from http://www.business.unsw.edu.au/nps/servlet/portalservice?GI_ID=System.LoggedOutInheritableArea&maxWnd=_CPS_DiscussionPapers_2006
- Bellini, F., & Bottolo, L. (2008). Misspecification and Domain Issues in Fitting Garch(1, 1) Models: A Monte Carlo Investigation. *Communications in Statistics - Simulation and Computation*, 38(1), 31-45. doi: 10.1080/03610910802395653
- Blake, D., Cairns, A. J. G., & Dowd, K. (2001). Pensionmetrics: stochastic pension plan design and value-at-risk during the accumulation phase. [doi: DOI: 10.1016/S0167-6687(01)00082-8]. *Insurance: Mathematics and Economics*, 29(2), 187-215.
- Brüggemann, R., & Lütkepohl, H. (2005). Practical Problems with Reduced-rank ML Estimators for Cointegration Parameters and a Simple Alternative*. *Oxford Bulletin of Economics and Statistics*, 67(5), 673-690. doi: 10.1111/j.1468-0084.2005.00136.x
- Butt, A., & Deng, Z. (2010). *Investment Strategies in Retirement*. Paper presented at the 18th Annual Colloquium of Superannuation Researchers University of New South Wales, Sydney.

- Carter, J. (1991). The Derivation and Application of an Australian stochastic Investment Model. *Transactions of The Institute of Actuaries of Australia*, 315-428.
- Dunn, P. K., & Smyth, G. K. (1996). Randomized Quantile Residuals. *Journal of Computational and Graphical Statistics*, 5(3), 236-244.
- Gallagher, P. (2011). Treasury Measurement of Retirement Income Adequacy, from http://www.feal.asn.au/multiattachments/3282/DocumentName/Forum11_Phil_Gallagher.pdf
- Ganegoda, A. (2007). *Explaining the Demand for Life Annuities in the Australian Market*. CPS Discussion Paper Centre for Pensions and Superannuation, The University of New South Wales, Sydney.
- Ganegoda, A. (2012). *Measuring Risks in the Financial Services Industry* Degree of Doctor of Philosophy University of New South Wales, Sydney, Australia.
- Ganegoda, A., & Evans, J. (2012). A framework to manage the measurable, immeasurable and the unidentifiable financial risk. *Australian Journal of Management*, 30(1). doi: 10.1177/0312896212461033
- Gilbert, R. F. (1994). Estimates of earnings growth rates based on earnings profiles. *Journal of Legal Economics*, 4, 1.
- Harris, G. (1994). On Australian Stochastic Share Return Models for Actuarial Use. *The Institute of Actuaries of Australia Quarterly Journal*, 34-54.
- Institute of Actuaries of Australia. (2002). Superannuation and Standards of Living in Retirement – Modelling Assumptions, Report to the Senate Select Committee Inquiry into Superannuation and Standards of Living in Retirement, September 2002
- Keegan, M., Harding, A., & Kelly, S. (2011). *The Adequacy of a Mature Superannuation System: A Dynamic Microsimulation Analysis*. Paper presented at the 19th Annual Colloquium of Superannuation Researchers, University of New South Wales, Sydney.
- Leow, J., Murphy, S., Hooper, G., & CCH Australia Limited. (2008). *Australian master superannuation guide 2008/09* (12th ed.). North Ryde, N.S.W.: CCH Australia.
- Mikosch, T., & Stărică, C. (2004). Nonstationarities in Financial Time Series, the Long-Range Dependence, and the IGARCH Effects. *The Review of Economics and Statistics*, 86(1), 378-390.
- Morrison, T., & Kelly, S. (2007). Superannuation-the Right Balance? : CPA Australia Ltd.
- Müller, U. A., Bürgi, R., & Dacorogna, M. M. (2004). Bootstrapping the economy--a non-parametric method of generating consistent future scenarios. *Munich Personal RePEc Archive*(MPRA Paper No. 17755).
- Murphy, K. M., & Welch, F. (1990). Empirical Age-Earnings Profiles. *Journal of Labor Economics*, 8(2), 202-229.

- Nielson, L., & Harris, B. (2010). Chronology of superannuation and retirement income in Australia *Information, Analysis and Advice for the Parliament, Background Note*: Parliamentary Library.
- Politis, D., & Romano, J. (1994). The Stationary Bootstrap. *Journal of the American Statistical Association*, 89(428).
- Poterba, J., Rauh, J., Venti, S., & Wise, D. (2007). Defined contribution plans, defined benefit plans, and the accumulation of retirement wealth. [doi: DOI: 10.1016/j.jpubeco.2007.08.004]. *Journal of Public Economics*, 91(10), 2062-2086.
- Rice Warner Actuaries. (2010a). Superannuation Adequacy: The Investment and Financial Services Association (IFSA).
- Rice Warner Actuaries. (2010b). Superannuation Savings Gap 2008: Investment and Financial Services Association (IFSA).
- Rothman, G. (2003). *Tax Advantages of Investment in Superannuation—In Bad Times as well as Good*. Paper presented at the 8th Colloquium of Superannuation Researchers, University of New South Wales, Sydney.
- Rothman, G. (2011). *Projecting the Adequacy of Australian Retirement Incomes* Paper presented at the 19th Colloquium of Superannuation Researchers, , University of New South Wales, Sydney.
- Saunders, P., Patulny, R., & Lee, A. (2004). Updating and Extending Indicative Budget Standards for Older Australians", Prepared for Association of Superannuation Funds of Australia by Social Policy Research Centre, University of New South Wales.
- Sherris, M., Tedesco, L. M., & Zehnwrith, B. (1999). Investment returns and inflation models: some Australian evidence. *British Actuarial Journal*, 5(1), 237-267.
- Sherris, M., & Zhang, B. (2009). Economic Scenario Generation with Regime Switching Models. *SSRN eLibrary*.
- The Australian Institute of Superannuation Trustees. (2011). 'Super'-poor but surviving: Australian women in retirement
- Wilkie, A. D. (1986). A Stochastic Investment Model for Actuarial Use. *Transactions of the Faculty of Actuaries*, 39, 341-403.
- Wilkie, A. D. (1995). More on a stochastic asset model for actuarial use. *British Actuarial Journal*, 1(5), 777-964.
- Zumbach, G. (2000). The pitfalls in fitting GARCH(1,1) processes *Advances in Quantitative Asset Management*, edited by Christian Dunis, : Kluwer Academic Publisher.