

**Abstract**  
**15<sup>th</sup> Colloquium of Pension Researchers**  
**When ordinary people choose between investments**  
**A study into the effects on individuals of investment risk and longevity risk**

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## **Abstract**

Australia's experiment with Superannuation is placing an increasing amount of the assets of economy under the ownership of individuals through the Superannuation System. Although the majority of people do not routinely exercise control, those that do, are likely to be influenced by a range of behavioural factors.

The paper reviews the implications for superannuation investors faced with longevity risk. It develops and presents scenarios for the effects on individuals of variations in investment returns, and argues that these effects are likely to be considered by investors in conjunction with their consideration of longevity risk. The paper proposes that individuals faced with a combination of their perceived risk in running out of money, or living too long, will progressively reduce their risk profile based on immediate history of performance, or survivorship. Because of the well documented asymmetric responses by investors to losses and gains, the paper argues that the aggregate of investor individual responses will be to reduce risk, and that this explains the industry response to offer lifecycle products that reduce risk with age.

The paper ends by arguing that this creates an arbitrage opportunity for the industry to offer portfolio insurance to those people post retirement, and that this insurance will allow greater opportunity for risk taking, and potentially allow for improved funding in the face of longevity risk.

## Index

Abstract.....	1
Introduction.....	3
Portfolio Choice and the dispersion of returns .....	6
The dispersion of portfolio returns.....	6
The effect on individuals of the dispersion of portfolio returns .....	8
The longevity risk and investment risk at the individual level .....	9
Modelling the effects of Longevity Risk and Target Return Risk.....	13
The way people choose .....	17
Behavioural Response to Risk and Return .....	17
Summary.....	19
Appendix 1: SuperRatings Survey of ‘Default’ Funds .....	20
Appendix 2: Baseline Model and Assumptions.....	21
Appendix 3: Results of 100 Runs using a Monte Carlo simulation approach for a person aged 65, retired and exposed to variations in investment return .....	22
Appendix 4: Summary of results of the Monte Carlo Simulation .....	29
References.....	30

## Introduction

In common with many countries experiencing an aging population and pronounced demographic shifts in population, Australia is looking at various public policy responses to funding retirement. Australia, somewhat like the US (with the 401k plans) has adopted a largely defined contribution (DC) system called ‘superannuation’ as the basis for retirement savings, supplementing an existing means-tested ‘age-pension’ set at 25% (40%) of adult average weekly ordinary time earnings (AWOTE) for individuals (couples), and of course individual savings. Over time, superannuation is expected to provide an increasingly greater proportion of retirement savings. This paper will examine the implications of longevity risk and of the investment choice in superannuation savings by individuals, and will not assess the interaction between superannuation and other forms of retirement funding.

The imputed benefits of a DC system include portability of savings; independence from employer for an increasingly mobile and flexible workforce; and of course ownership. The last aspect is becoming more evident with research by ASFA<sup>1</sup> and large industry funds showing that the majority of people are aware of superannuation, and are starting to take a real interest in this given that it is becoming the second largest asset outside the family home. In aggregate, this DC system has resulted in Australia having the 4<sup>th</sup> largest pool of investible assets in the world<sup>2</sup>, and arguably one of the most sophisticated methods of funding retirement savings.

However, in contrast to other countries such as Norway and Sweden that have developed systemic responses to retirement funding, the characteristic of the DC system means that in Australia, the individual bears the entire investment risk of their superannuation savings even while arguably this means that there is a greater relationship being created between the individual and their retirement funding.

Lien (2007) argued that, in Norway, the societal association with the Norwegian Pension Fund is sufficient to enable Norwegians to have a relationship with their retirement funding, without the need for individual accounts. While, in Australia, this greater ownership has led to a substantial proportion of the population supplementing the government legislated funding, the paper will argue that this individual relationship can result in reduced risk taking as the individual becomes an aged survivor, or where the immediate past performance of the asset has resulted in a less than expected return.

On a macroeconomic level, Nishiyama (2005) argued that the effects of privatising a portion of the pension system in small open economy (which Australia is arguably) led to a significant increase in overall wealth. Nishiyama includes the effects of a Social Security system operating to partially offset wages shock and longevity risk, and argues that “households re-optimize their lifecycle choices after the policy change” to produce some of the efficiency gains.

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<sup>1</sup> Association of Superannuation Funds of Australia (ASFA) is one of a number of large and very influential industry bodies with highly respected research capabilities.

<sup>2</sup> The Australian Government Publication : AXISS 2006

Of course, individual ownership of a portion of savings will need to provide additional societal benefits to offset the individual risk. In a DC environment, the available wealth for retirement will increasingly be as a result of investment returns the investment and product choices rather than just the mean return on investments.

In addition, very few investors actually choose between investment options, and few change funds.<sup>3</sup> As a result, around 50% of investors implicitly allow the choice to be made for them by relying on their employers to select their fund<sup>4</sup>, and on the fund trustee to select the investment choice. Investors therefore allow their savings to be invested in 'default' funds.

Furthermore, in the situations where investors make decisions, those decisions are often coloured by behavioural, gender or demographic factors. McNaughton (2006) showed that in Australia, even under conditions where professional advisers were providing decision support, decision making by investors varied by sex, age and attitudes.

Livanas (2006B) concluded that investors' choices conformed to the value functions proposed by Kahneman (1979) in that utility was asymmetric for gains versus losses. A further finding in this paper was that investors did not show any discrimination on time horizon in making investment decisions – a conclusion that will be increasingly important in situations where investors are asked to make portfolio decisions based on their assessment of longevity risk. Livanas (2007) further concluded that portfolio insurance would add utility to investors by limiting losses.

The paper continues the focus on impact on the individual investor and their investment behaviour and is set out as follows:

Utilising data from Superratings for superannuation returns over the last 5 years, the paper reviews the dispersion of returns from superannuation funds and comments on the impact on an individual level. This is significant in cases where portfolio insurance is not efficient, as noted by Mitchell (2006) who specifically reviewed the failure of markets to provide some sort of longevity risk insurance.

The paper then develops a model for an investor who survives to age 65 and wishes to fund retirement until their expected age at death of 83 (the 'target date') – being the mean age at death of their cohort. This model is run 100 times using a Monte Carlo like simulation for investment returns, to develop a likelihood that the investor will either run out of money before their target date for their portfolio, or indeed, will, through natural variation of returns, actually have sufficient money even though they have exceeded their anticipated lifespan.

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<sup>3</sup> Recent industry research showed that only 1 in 5 superannuation investors were highly likely to consolidate accounts

<sup>4</sup> APRA Annual Superannuation Bulletin 2006 (issued 22 March 2007) from [www.apra.gov.au](http://www.apra.gov.au). The Australian government has enacted laws to allow members to move between funds, philosophically arguing that more choice, and specifically more competition, will create a more efficient market for superannuation investors.

The paper draws on this preliminary analysis to assess the experience of the individual investor, and assess the industry response.

Finally, the paper concludes that portfolio insurance can be effective in arbitraging the sum of investor responses at an aggregate level.

## **Portfolio Choice and the dispersion of returns**

Superannuation members have an increasing variety of options available to them in selecting the portfolios through which to invest their superannuation. Around half the employees allow their superannuation savings to be invested in whatever fund the employer has selected as a default fund<sup>5</sup> and in whatever investment option is the default option for that fund. In some cases the portfolio may vary in accordance with the age of the employee (a process known generally as lifecycle investing). Other employees, who select funds and investment options, will do so according to published risk-return characteristics, often described by the percentage of assets allocated to 'growth' assets. 'Growth' assets are generally as defined by the industry and include equities and listed property.

Over the last decade, there has been the parallel emergence of a number of organisations that operate to amalgamate and publish the performance of superannuation funds and their investment options. These organisations include 'SuperRatings', 'Rainmaker', 'Dexxr', and 'RiceWarner'.

This section utilises figures published by 'SuperRatings' to show the dispersion of annualised 5 year returns from a number of large superannuation funds and then uses the returns of the 'default' investment option of the funds responding to the SuperRatings survey, to develop a model of investor experiences at an individual level. In both cases 5 year annualised return and annualised standard deviation numbers have been used, as available at 30 April 2007.

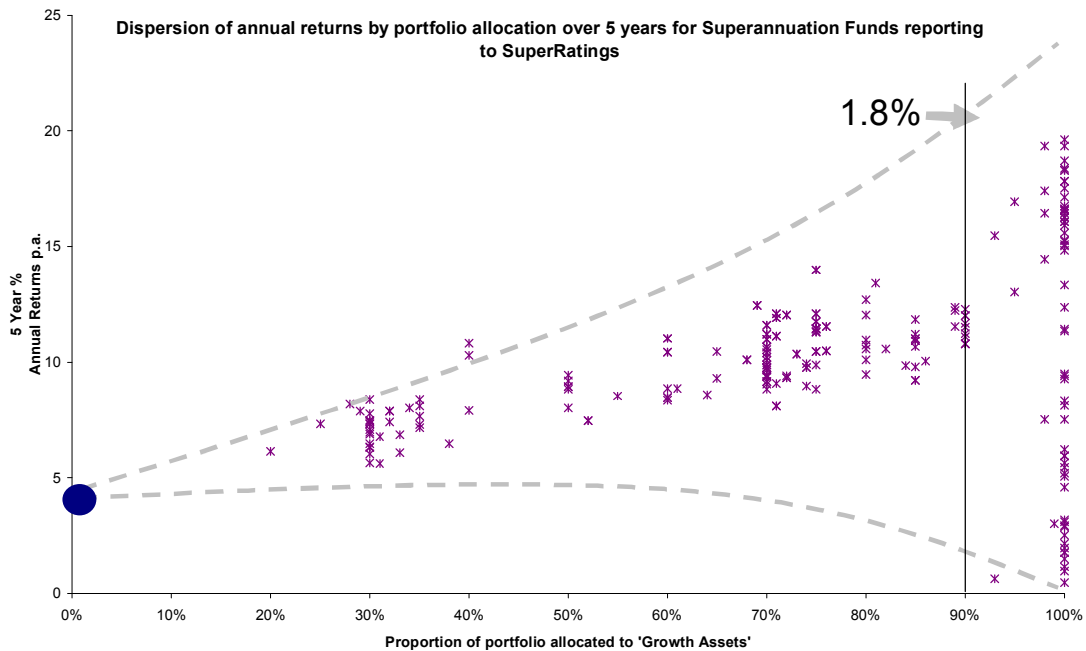
### ***The dispersion of portfolio returns***

Figure 2 below shows that the dispersion of annualised returns for all superannuation funds over \$200m relative to their reported allocation to growth assets.

As expected, the returns increase as the portfolio shows a greater allocation to growth assets. However, as anticipated, the figure also show a marked increase in dispersion of returns as the proportion of assets allocated to growth assets approaches 100%. (It is worth noting that only 1.8% of assets by value are described as having a 100% allocation to 'Growth Assets').

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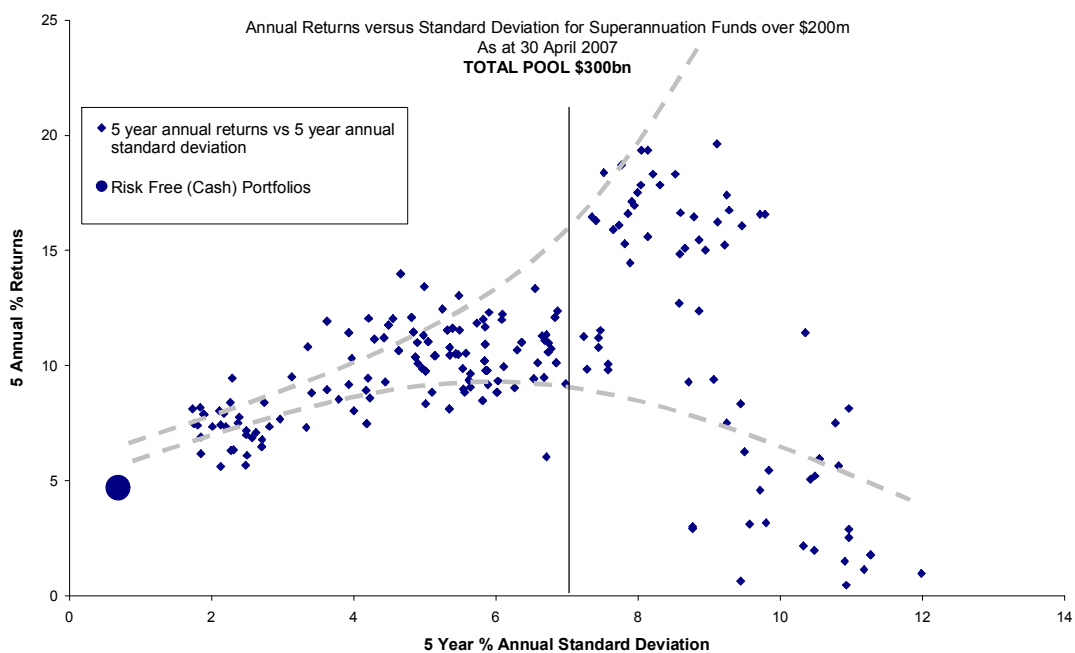
<sup>5</sup> The superannuation system in Australia defines superannuation contributions as contributions made by employers on behalf of employees and where there is no explicit choice made by the employee, the employer is obligated to remit their employee superannuation contributions to a default fund that is selected formally by an employer. The default fund is generally a 'corporate fund', and 'industry fund' a 'mastertrust' or a 'retail fund', each of which are structures the governance of what are in essence mutual funds.



**Figure 1** The dispersion of annualised returns versus the allocation to ‘Growth Assets’ over 5 years to April 2007 reporting to SuperRatings

Again, this is the expected pattern of dispersion. The large “Blue” marker at 0% allocation to ‘Growth Assets’ is the notional ‘risk-free’ using the returns on the ‘cash’ portfolio options of the funds.

An analysis of the annualised 5 year standard deviation of the portfolios compared to the returns is as shown in Figure 2 below:



**Figure 2** Annualised returns versus annualised standard deviation over 5 years to April 2007 for portfolios in superannuation funds reporting to SuperRatings

Again the dispersion is as expected, with returns broadly correlated to standard deviation of returns. It should be noted that just 2.8% of investments by asset value account for markers to the right of 7% annual standard deviation.

On an aggregate basis therefore it can be argued that the pattern represented in figures 1 and 2 above, are broadly as predicted in theoretical models.

According to APRA, the majority of superannuation investors are passive in their initial choice with 17% of funds (by asset value) not offering investment choice, and with around 50% of members are in the default strategy<sup>6</sup>.

Consequently, the returns in the ‘default’ portfolios are of great interest. The variation of returns for the chosen ‘default’ portfolio in the ‘default’ fund is shown below:

**Table 1 Annualised Investment Returns for the nominated ‘Default’ Portfolio**

<b>“SuperRatings” Fund Crediting Rate Survey - Default Options</b>				
<b>Fund Investment Option</b>	<b>5 Year Return</b>	<b>10 Year Return</b>	<b>5 Year Std Deviation</b>	<b>5 Year Sharpe Ratio</b>
Top Quartile	10.3	10.1	4.7	1.1
Bottom Quartile	8.5	8.9	5.6	0.6
All Fund Median	9.1	9.3	5.2	0.9
Maximum Value	13.7	11.1	7.1	1.7
Minimum Value	6.4	7.3	3.0	-1.1

Again, the returns shown are broadly as expected with the standard deviation broadly defining the dispersion of returns for the universe of portfolios (i.e. the variation can be accounted for through the standard deviation rather than other factors).

### ***The effect on individuals of the dispersion of portfolio returns***

While the dispersion of aggregate returns are generally representative of those expected according to risk and return, the returns experienced by the individual correspond to just one return marker.

Assuming for the moment that the top and bottom quartile returns as shown in Table 1 above, are experienced by two superannuation investors, and assume that the annualised returns are distributed evenly and that the superannuation investors contribute \$10,000 p.a. at the start of each year and have an opening balance of \$30,000, the position at the end of April 2007 for these two investors are as shown in Table 2 below:

The table shows that the variation in returns at an individual level can significant, and that this may lead to behavioural responses that are different between investors that are invested in portfolios with the same aggregate risk-return characteristics.

<sup>6</sup> APRA Annual Superannuation Bulletin June 2006 (Issued 22 March 2007) available from [www.apra.gov.au](http://www.apra.gov.au)



**Table 2 Comparison of Returns experienced by two investors, one of whom receives the top quartile of annual returns, the other who receives the bottom quartile of returns**

Top Quartile	Apr-03	Apr-04	Apr-05	Apr-06	Apr-07
Opening Balance	30,000	44,104	59,655	76,802	95,708
Contributions	10,000	10,000	10,000	10,000	10,000
Returns	4,104	5,551	7,147	8,906	10,846
Closing Balance	44,104	59,655	76,802	95,708	116,553

Bottom Quartile	Apr-03	Apr-04	Apr-05	Apr-06	Apr-07
Opening Balance	30,000	43,392	57,920	73,679	90,775
Contributions	10,000	10,000	10,000	10,000	10,000
Returns	3,392	4,528	5,760	7,096	8,546
Closing Balance	43,392	57,920	73,679	90,775	109,321

### ***The longevity risk and investment risk at the individual level***

Just as for investment returns, longevity risk in DC funds operates at an individual level. For the purposes of this paper, this risk is defined as the probability that the individual will live to a lesser or greater age than the population median for his/her gender.

However the utility gained or lost by the individual is likely to be asymmetric dependant on whether the individual lives older than the mean age, or less than the mean age of their cohort. For the individual who lives less than the mean age there are several arguments (based on the overlapping generations model – OLG, and bequest models) that the individual gains utility by bequeathing the balance of their funds to their progeny.

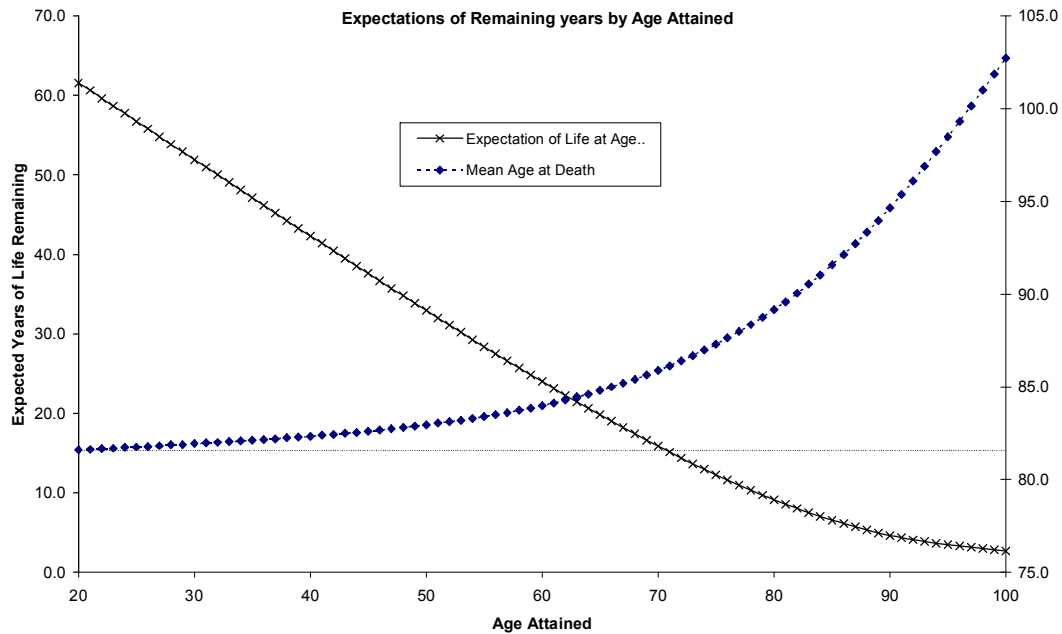
For those that live more than the mean age, the individual gains utility in living, but loses utility in the bequest motive and in their own consumption. (In Australia this is partially offset by access to the ‘age-pension’)

The various components in constructing longevity risk at an individual level are shown in Table 3 below:

**Table 3 Effect on the individual of longevity**

<b>The way the individual sees their own situation</b>	Individual lives less than the median (mean) age of his/ her cohort	Individual lives more than the median (mean) age of his/ her cohort
<b>Gains</b>	<ul style="list-style-type: none"> <li>• Greater utility from being able to pass on greater amount to the next generation</li> </ul>	<ul style="list-style-type: none"> <li>• Greater utility from a greater life span</li> <li>• Greater utility from access to safety net</li> </ul>
<b>Losses</b>	<ul style="list-style-type: none"> <li>• Reduced utility from a shorter lifespan</li> </ul>	<ul style="list-style-type: none"> <li>• Reduced utility as a result of running out of money</li> </ul>

Figure 3 below is a chart of expectations of life by age of survival. A survivor at 65 is in fact likely to achieve a greater age at death than is likely for one at birth, merely by virtue of surviving to age 65. (The graphs based on the Australian Life Tables<sup>7</sup>).



**Figure 3 Australian expected years of life remaining versus age attained**

The tables show that individuals expected age at death increases very slowly up until middle age, and increases more rapidly after age 65. This creates an interesting dilemma! Longevity risk is reasonably stable until the investor retires, after which, as the investor ages, their chance of living longer increases. As a result, survivors, by virtue of their survival alone, are subject to greater and greater personal longevity risk. This may have implications for survivors' risk profiles as we shall see later.

Mitchell (2006) also showed that investors are unreliable predictors of the impact of time on the value of money. Furthermore, Livanas (2006B), using choice modelling, showed that investors did not respond to differing time horizons with changes in favoured investment risk-return profile, thereby not optimising on the basis of time. Furthermore, investors' assessment of risk was based on immediately historical experience, either in their individual returns or of the market.<sup>8</sup>

Constructing a function for an individual in the face of longevity risk requires the individual to maximise utility in the face of consumption versus bequest; the risk of

<sup>7</sup> Australian Bureau of Statistics: ABS cat. no. 3302.0.55.001 Life tables, Australia, 2003–2005 and author's calculations

<sup>8</sup> Confidential industry research also shows that investors will review their portfolio, on average around once a year up until retirement. From then onwards they will review their portfolio on average twice a year. Furthermore, investors will use these returns as signals for their risk assessment, and while they may not respond to change funds or investments immediately (largely as a result of inertia), they will nevertheless have a change in their perceptions of their utility, with losses providing a greater disutility per unit than gains (Livanas 2006C).

money running out versus social security (age pension) top ups; capacity to work; risk aversion and social security top ups.

Nishiyama's model may be relevant given that it models investor reaction to partially privatised retirement savings system – which seems to correspond to the practice in Australia and the USA. Reviewing the household value function as developed by Nishiyama (2005) we see:

$$v(s_i, S_i; \Psi_i) = \max u_i(c_i, h_i) + \beta (1+\mu)^\alpha (1-\gamma) \Phi_i E [ v(s_{t+1}, S_{t+1}; \Psi_{t+1} | e_i ]$$

Nishiyama's value function includes survivorship ( $\Phi_i$ ), and coefficient of risk ( $\gamma$ ), and time preference  $\beta$ ,  $s_i$  – the state of the household – as a function of age; hourly earnings; starting wealth and historical earnings; as well as the usual references to consumption  $c$ , capacity to work (captured by the utility function) and the state of the economy  $S_i$  and  $\Psi$  – a given policy schedule for social security and retirement funding among others

The utility function is defined as:

$$u(c_i; h_i) = \frac{\{((1 + n_i/2)^{-\zeta} c_i)^\alpha (h_i^{\max} - h_i)^{1-\alpha}\}}{1-\gamma}$$

where:  $n_i$  = the number of dependant children;  $\zeta$  is the adult equivalency scale,  $h_i^{\max}$  is the maximum working hours;  $h_i$  is the hours worked.

Following on from the fact that survivorship is largely stable under 65, it is also the pattern that people over 65 will have fewer and fewer dependants. Nishiyama's model is interesting in that it provides a specific savings response to variations in social security, in household age and by wealth (earning ability) octiles. This provides a more granular approach to many other models. However Nishiyama seems to include a static risk factor for all age cohorts and furthermore, doesn't allow for response to variation in investment returns for common wealth cohorts.

It is precisely this dispersion of returns that forms an important factor in assessing household response and may result in changes in risk attitude varying by age. A household in reality is being asked to consider a joint probability function of longevity risk and investment returns and adjust investment accordingly.

If we exclude the capacity of the individual to defer retirement or to limit consumption, we see that the individual need to maximise utility in the face of a joint probability of: {longevity risk: return risk}, with survivorship by it's nature adding longevity risk, while immediate past underperformance, reducing risk propensity.

The longevity risk is the risk (in years) of living past the mean age for the individual's cohort; and return risk as the risk (in percentage ) of achieving a return less than the mean for the asset risk class can be described by a value function at age  $i$ , as follows:

$$v(i) = P(Eox > mean) \cdot P(Return < mean)$$

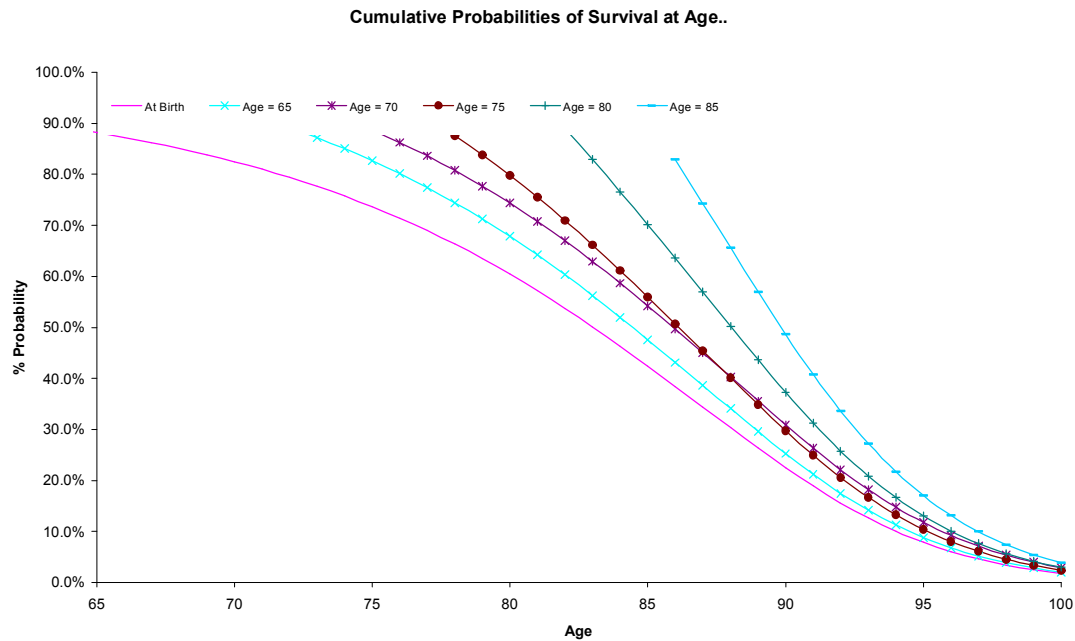
Where  $Eox$  is the individuals expected age at death.

The longevity risk is then:

$$LR = \prod (1-q_x)$$

Where:  $q_x$  is the proportion of people dying at exactly age  $x$ .

The longevity risk is shown graphically in figure 4 for survivors at specific ages, and is based on the Australian Life Tables and author's calculations weighted for males and females together:



**Figure 4 Cumulative probabilities of survival at birth; ages 65 to 85 (in 5 year cohorts)**

If, in turn, we assume that the probability of achieving a return less than the mean in any one year is assumed gaussian, and the returns of an efficient market over any time horizon with a positive risk free rate, are lognormal such that:

$$E = Be^r$$

Where:  $E$  = End Value,  $B$  = Beginning Value and  $r$  is the return rate

Then commonly, the probability of achieving a target return value (TRV) over a time horizon with a number of periods  $n$  is given by:

$$Z_{TRV} = \frac{\text{Log}_e\left(\frac{T}{B}\right) - \text{Log}_e(1+R_g)n}{S \sqrt{n}}$$

Where:  $B$  = Beginning Value

$T$  = Target Value

$R_g$  = Geometric Average of holding period returns

$S$  = Standard Deviation of the logs of (1+ Holding Period Returns)

So then, the joint effects of the longevity risk, and the probability of not achieving a targeted future value, can be defined as:

Probability of living longer than mean

*and*

Probability of achieving an average return below the expected mean for the risk taken

An individual therefore is likely to assess the likelihood of running out of money as a result of investment returns in conjunction with the probability of living to the expected age (83). It is this joint assessment that this paper is addressing.

### ***Modelling the effects of Longevity Risk and Target Return Risk***

A simulation model (Appendix 2) was set up to assess the likely distribution of savings for someone who is retiring at 65 and expecting to live to 83 (the gender weighted mean age at death as estimated from the Australian Life Tables).

The model was calibrated to assume the following parameters:

**Table 4 Model Parameters**

Parameter	Value	Explanation
Age at retirement =	65	
Expected Age at Death =	83	
Amount at Retirement =	\$200,000	
Bequest at age 83	Nil	
Expected Return	9.1%	Annual Return <sup>1</sup>
Expected Standard Deviation	5.2%	Annual Standard Deviation <sup>2</sup>
Consumption Inflation	3% p.a.	

1 Annualised median return for 5 years ending April 2007 for the default investment option of funds reporting to SuperRatings

2 Annualised standard deviation for 5 years ending April 2007 for the default investment option of funds reporting to SuperRatings

The model was first run to establish a baseline of consumption (or portfolio drawdown) for which there would be no terminal value of funds at death. The baseline assumed that returns would be paid at the end of each year after consumption had occurred, that the expected returns would equal the annual median return of 9.1% without variation and that the individual would be retiring at 65, with \$200,000 in assets.

The model was solved for a Year 1 consumption figure that would achieve all these objectives given a further assumption that consumption would be expected to increase each year by 3%.

Once the baseline model had been calibrated, the model was run 100 times, with the only variation being the investment return each year. Each run allowed the annual investment return to vary in a Monte Carlo style simulation, according to the mean

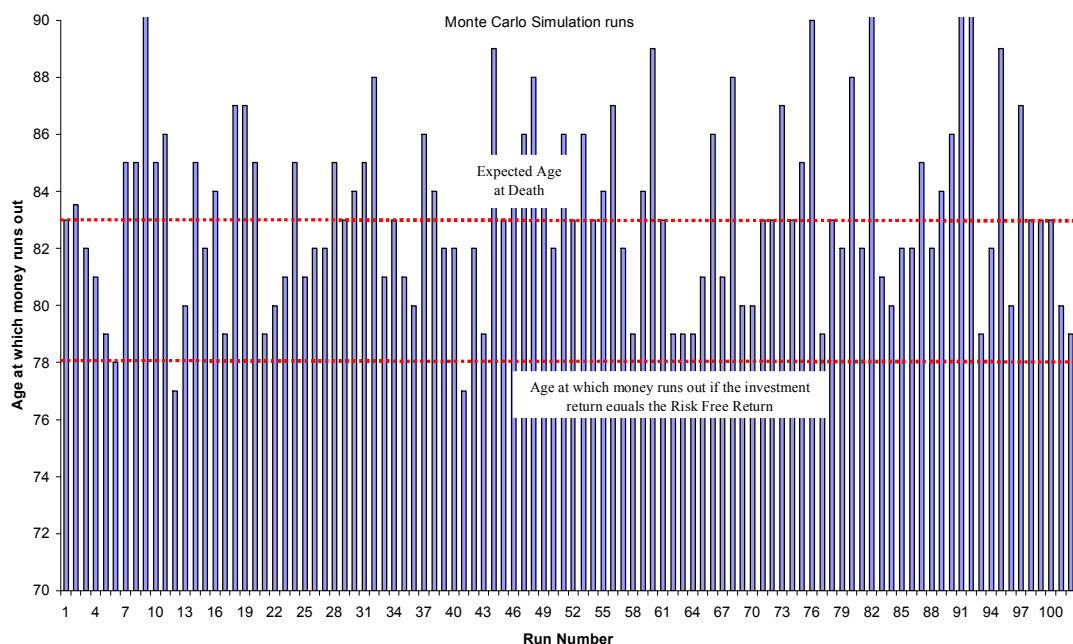
and standard deviation of the default funds as defined in Table 4. A further check was put in place to ensure that the average of the returns and the average of the standard deviations of all 100 runs were similar to that of the baseline model. When these were within 1 basis point of the expected returns, the model was ‘locked down’.

The purpose of the modelling was to determine impact on the individual rather than to assess the aggregate. Too often models miss the impact on individuals; it is the individual behavioural response that this paper is interested in. While the aggregate of the mean and standard deviation of the returns is known, the individual response will be dependant on the individual experience, and with asymmetric responses to losses versus gains, the sum of the individual responses will be different from the imputed response of the aggregate result.

The specific focus of the model is for retirees over 65. The model can be run for other age groups, and greater complexity can be added to allow for the interaction of the potential for additional earnings, lowered consumption, deferred retirement, and the costs of children. Nishiyama’s model perhaps can be modified to achieve this, but for the purposes of assessing longevity risk, the model assumes survivors at 65.

The simulations are contained (in some detail) in Appendix 3.

The pattern of people achieving an individual return which allows then achieve their objective of funding their consumption until death at 83, is shown in Figure 5 below:

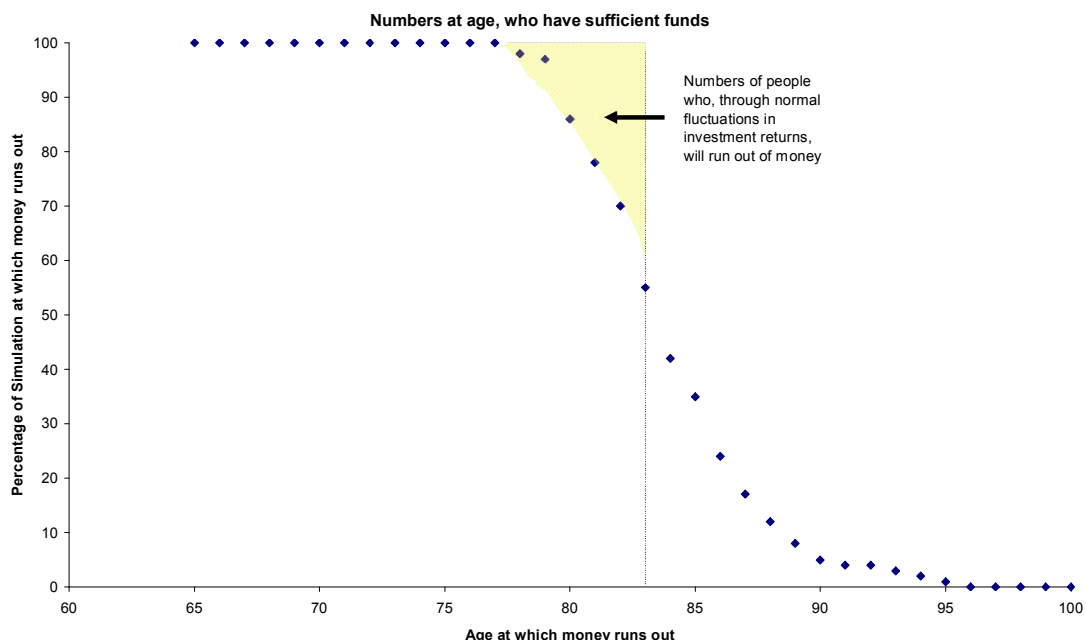


**Figure 5 Chart of Runs for individuals given constant consumption patterns**

Unsurprisingly, a large number of people will run out of money prior to death – assuming again that all die at exactly 83. This is due to the natural variation in returns and their effect on the individual’s portfolio as modelled in Appendix 3. Nevertheless, the alternative of individuals investing in the risk free rate (4.70%, or the cash rate of return from the superannuation funds reporting to SuperRatings), will result in 100%

of individuals running out of money at age 78!<sup>9</sup> As a result, a policy response to limit investment risk is not efficient.

Figure 6 below develops figure 5, and shows a plot of the distribution of the results by age at which the money runs out. It continues the story that, while longevity risk is important, the additional risk through normal variation in investment returns is often overlooked.



**Figure 6 Plot of numbers from Runs, at age which money runs out**

By age 80, with an expectation of life until age 83, close to 15% (according to the simulation) will have run out of money as a result of natural variation. These people will be faced with an equivalent risk to those expecting to live three years longer than 83.

Given that this simulation is only modelled on the current standard deviation and returns from the aggregate of default funds, it is likely that a greater variation in returns will be experienced if the entire universe of investment options was selected. Given then that the model is concerned asymmetrically with returns (i.e. underachieving targeted returns), it is conceivable that the impact will be greater than shown in figure 6. This is developed further in the next section.

Drawing together the theme of investment risk and longevity risk, figure 7 below shows the probabilities of each on a single chart:

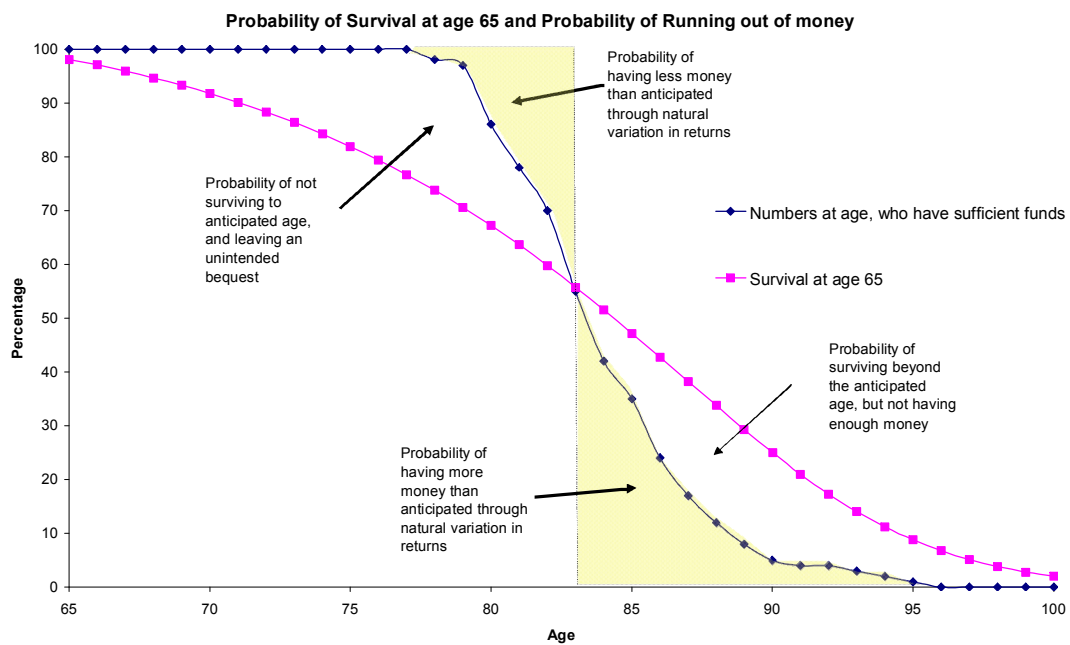
The chart shows that, on an individual level, people will face one of four scenarios – not surviving to anticipated ‘average’ age, and either having enough money to live to this ‘abbreviated age’, or through a variation in returns, even then running out of money. Alternatively they can face longevity risk, and run out of money, or, through a

<sup>9</sup> This model is available on request and is merely the baseline model run at a rate of return of 4.70%.

variation in returns, actually have money to continue their previous consumption patterns.

In figure 7, a survivor at age 65 has a probability of 40% of surviving as additional 3 years.

Of course the corollary also exists – and the figure below shows that investment returns will, through natural variation, provide sufficient funds for around 15% of people who survive until age 86.



**Figure 7 Probability of Survival and Probability of running out of money, by age**

This brings two specific issues in question:

1. From a behavioural perspective, given that investors’ response to losses is greater per unit loss than it is to gains, as investors age their longevity risk increases. For the number of investors who experience a temporary underperformance in their portfolio returns, these investors will tend to naturally reduce their risk profiles. Overall this may reduce average returns and potentially create an environment where the sum of DC funds will return less than a grouped plan.
2. If the natural variations in returns at individual level create a bias in reduction of risk through an asymmetric response of investors to losses compared to gains, this should create a natural arbitrage for portfolio and longevity risk insurance, and that would add efficiency at a grouped level allowing for greater risk taking at an individual and aggregate level.



## The way people choose

The previous section showed that investors are subject to variation in returns from normal portfolio variations in addition to longevity risk. In response to both risks, the investor is faced with a decision to optimise their portfolio for a 'target date' that is well in the future, and then progressively review their portfolio as they become likely to live beyond the mean age for their cohort.

Furthermore, during their investment period (during both the accumulation and draw down phases), investors will gain or lose in their perception of utility merely through the act of reviewing the performance of their portfolio. This can sometimes lead to investors revising their portfolios or changing funds altogether. (Livanas 2007)

There is a common expectation that as investors approach retirement age the risk taken by their portfolio should reduce. As a result, many organisations are introducing 'life-cycle' style funds that provide for stepped reduction in portfolio risk. Bodie (2006), following Samuelson (1952) argues that investor risk profiles should not be redressed as a function of time to retirement, but only as a function of the investor's risk profile. And yet, as lifecycle style investing is becoming more popular, an emerging argument seems to be that investor risk profiles in fact do change as they near retirement or some target date, with the argument put forward that investors' capacity to recover from losses reduces. Optimising portfolio design over long periods of time is still a matter of significant controversy, and constructing portfolios that reflect investor risk accurately, still an art. It is instructive to recall Merton (1974) pp68:

*“Unfortunately, as has been pointed out repeatedly, the mean-variance criterion is rigorously consistent with the general expected-utility approach only in the rather special cases of a quadratic utility function or of gaussian distributions on security prices – both involving dubious implications.....recent dynamic simulations have shown that the behavior over time of some efficient mean-variance portfolios can be quite unreasonable..”*

Further, Merton pp73 argues that optimising utility:

*“..will not involve portfolio decisions constant through time..”*

This section will question whether investor utilities do indeed change as the risks that they face change.

### **Behavioural Response to Risk and Return**

Figure 7 above and the Australian Actuarial tables show that the longevity risk is largely the same until around age 65, at around which point survivorship starts increasing the chance of the individual living longer than the mean for their cohort.

Figure 7 also imputes that the variations in the return of a portfolio constructed with a target date in mind, will result in differences in the perspective of an individual.

Both these factors operate only at an individual level. At an aggregate level, the mean of the portfolio returns will prevail and the expected return will, in all likelihood, be achieved.

However, if the asymmetric responses of individuals to losses and gains (Kahneman 1979 and Livanas 2006B) are compiled, the overall “risk” profile of the aggregate of all portfolios is likely to be reduced.

To demonstrate simply:

$$\sum EU_i (\text{Gains}) + \sum EU_i (\text{Losses}) < \sum EU_t (\text{Net of Gains and Losses})$$

Where  $EU_i$  is the Expected Utility for the  $i$ th investor,  $EU_t$  is the aggregate expected utility of the universe. (This can be set in relative terms at zero)

Livanas (2007) showed that investors are seemingly unable to contemplate accurately differences in portfolio time horizons where they are greater than a year. So therefore, a rational response to this, is that for those investors who see that their portfolio returns are less than anticipated as they near their ‘target date ‘ (or age at which they expect to die), they will reduce risk given that they have experienced a relative loss. Investors therefore will rely on the immediate history in their behavioural response, rather than in a forward looking assessment of time remaining for their portfolio.

This also explains people’s response to longevity risk insofar as the risk of living longer than their cohort should in theory require greater risk taking in order to have a chance to meet their objectives of ‘not running out of money’. People’s inability to accurately contemplate future returns (to understand the time value of money or indeed time horizons in portfolios) means that investors will respond to immediately prior stimuli.

On an industry wide level, a rational response is to reduce the likelihood of loss by offering a lower risk portfolio given that the utility of losses at an individual level outweigh the utility of gains, even if on an aggregate level, the response is to reduce overall risk and possibly return.

In both cases this response will reduce returns at the aggregate level. An efficiently functioning market should serve to arbitrage on the differences in utility for losses and gains to allow for greater individual risk to be taken, and thereby to allow for a greater aggregate return.

## Summary

This paper was written to consider possible behavioural impacts of longevity at an individual level. The paper reviewed the longevity risk faced by individuals, based on the Australian Life Tables. The paper then considered the investments risks faced by an individual, assuming that they were invested in the ‘default’ strategy<sup>10</sup>. Without considering other savings or the social security safety net of the ‘age pension’ in Australia, the paper presented results of a Monte Carlo style simulation, run for an investor who retired at age 65 and had an expectation of life until age 83. 100 runs of the model were presented and the results demonstrated that an investor who had invested in risky assets faced, in addition to longevity risk, the risk of their money running out prior to their expected death - merely as a result of natural variations in investment returns.

The model also showed that, as a corollary, the investor who lived beyond the mean age of their cohort could also, in some cases benefit from the beneficial effects of investment returns. Consequently, an investor investing in risky assets faced one of four scenarios:

- Not living to the mean age of their cohorts, but still running out of money
- Not living to the mean age of their cohorts, but leaving an unintended bequest
- Living beyond the mean age of their cohorts and running out of money (the normally stated longevity risk)
- Living beyond the mean age of their cohorts, but having sufficient money.

The paper postulated that the response of individuals facing fluctuations in returns (even as a result of natural volatility) or the uncertainty of age of death would be to become more risk averse. This is as a result of an asymmetric utility function, where losses “loom larger than gains”. As such, investors would be more likely to respond to losses than gains, and the sum of the individual responses would result in more risk aversion in aggregate, than would be the expected result when looking at the mean of returns or of longevity risk.

As a result the industry is likely to respond to this behaviour of people as they age, with investment options that are increasingly conservative and have a lower volatility (and potential return). However, this response would actually be counterproductive with the result that the overall investment returns decreasing as lower risk is taken<sup>11</sup> and retirement funding at the aggregate level reduced.

A better response may be for the industry to develop portfolio insurance which can arbitrage the natural differential between the individual pain, and group risk. Such an insurance would add utility to individuals by allowing them to take greater risks through more aggressive portfolios, providing for greater overall returns and a reduction in longevity and investment risk, even after the cost of insurance.

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<sup>10</sup> Default strategies are more common in the accumulation phase. However for the purposes of this paper, it is assumed that the investor continues to invest in the nominated default. The purpose of the paper is to illustrate the effects on individuals and their resulting behaviour, of normal variations in returns, rather than comment on aggregate strategies. Further analysis of the actual investment strategies post retirement may be interesting.

<sup>11</sup> This presumes of course that higher risks will, over time equal higher returns. This papers study of 5 year returns shows that this is still a reasonable assumption.

## Appendix 1: SuperRatings Survey of 'Default' Funds

SuperRatings Fund Crediting Rate Survey - Default Options				
Fund Investment Option	5 Year Return	10 Year Return	5 Year Std Deviation	5 Year Sharpe Ratio
Top Quartile	10.3	10.1	4.7	1.1
Bottom Quartile	8.5	8.9	5.6	0.6
All Fund Median	9.1	9.3	5.2	0.9
Maximum	13.7	11.1	7.1	1.7
Minimum	6.4	7.3	3.0	-1.1

The details of the funds utilised in this survey are available commercially from SuperRatings



### Appendix 3: Results of 100 Runs using a Monte Carlo simulation approach for a person aged 65, retired and exposed to variations in investment return

	Baseline	AVERAGE OF ALL RUNS				Run Number				
		1	2	3	4	5	6	7	8	9
1. Age at Retirement	65	<b>65</b>	65	65	65	65	65	65	65	65
2. Achieving the fund mean return of	9.10%	<b>9.09%</b>	9.17%	8.94%	9.02%	8.04%	9.80%	8.22%	10.21%	8.60%
3. Expected Bequest (Terminal Value at Death)	\$0	<b>\$0</b>	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
4. Expected Age at death of	83	<b>83</b>	83	83	83	83	83	83	83	83
5. No capacity to rely on age pension or additional income		<b>0</b>	0	0	0	0	0	0	0	0
6. Actual Terminal value at age 83 is	\$0	<b>-\$9,209</b>	-\$66,355	-\$71,258	-\$171,856	-\$209,830	\$44,602	\$48,653	\$228,353	\$43,397
7. Consumption inflation of	3%	<b>3%</b>	3%	3%	3%	3%	3%	3%	3%	3%
8. Annualised Standard Deviation of	5.20%	<b>5.19%</b>	3.99%	5.45%	5.74%	5.40%	4.35%	5.06%	5.66%	5.63%
9. Required Consumption to achieve bequest motive	-\$16,819	<b>-\$16,819</b>	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819
10 Age at which money runs out	83	<b>83.5</b>	82	81	79	78	85	85	93	85

	Baseline	AVERAGE OF ALL RUNS				Run Number				
		1	10	11	12	13	14	15	<b>16</b>	17
1. Age at Retirement	65	65	65	65	65	65	65	65	65	65
2. Achieving <b>the</b> fund mean return of	9.10%	9.09%	10.28%	8.56%	8.11%	9.84%	8.53%	8.05%	6.98%	9.20%
3. Expected Bequest (Terminal Value at Death)	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
4. Expected Age at death of	83	83	83	83	83	83	83	83	83	83
5. No capacity to rely on age pension or additional income		0	0	0	0	0	0	0	0	0
6. Actual <b>Terminal</b> value at age 83 is	\$0	-\$9,209	\$56,152	-\$220,864	-\$112,876	\$45,519	-\$62,154	\$10,128	-\$140,296	\$92,019
7. Consumption inflation of	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
8. Annualised <b>Standard</b> Deviation of	5.20%	5.19%	5.18%	6.19%	4.64%	4.47%	5.74%	6.08%	4.83%	6.17%
9. Required Consumption to <b>achieve</b> bequest motive	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819
10 <b>Age</b> at which money runs out	83	<b>83.5</b>	86	77	80	85	82	84	79	87

	Baseline	AVERAGE OF ALL RUNS		Run Number						
		1	18	19	20	21	22	23	24	25
1. Age at Retirement	65	<b>65</b>	65	65	65	65	65	65	65	65
2. Achieving the fund mean return of	9.10%	<b>9.09%</b>	10.10%	8.79%	8.28%	7.78%	9.07%	8.84%	8.24%	9.47%
3. Expected Bequest (Terminal Value at Death)	\$0	<b>\$0</b>	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
4. Expected Age at death of	83	<b>83</b>	83	83	83	83	83	83	83	83
5. No capacity to rely on age pension or additional income		<b>0</b>	0	0	0	0	0	0	0	0
6. Actual Terminal value at age 83 is	\$0	<b>-\$9,209</b>	\$99,806	\$57,924	-\$159,555	-\$105,413	-\$69,601	\$48,847	-\$90,031	-\$53,115
7. Consumption inflation of	3%	<b>3%</b>	3%	3%	3%	3%	3%	3%	3%	3%
8. Annualised Standard Deviation of	5.20%	<b>5.19%</b>	4.26%	5.53%	5.64%	4.75%	4.42%	4.63%	5.23%	4.86%
9. Required Consumption to achieve bequest motive	-\$16,819	<b>-\$16,819</b>	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819
10 Age at which money runs out	83	<b>83.5</b>	87	85	79	80	81	85	81	82

	Baseline	AVERAGE OF ALL RUNS		Run Number						
		1	26	27	28	29	30	31	32	33
1. Age at Retirement	65	<b>65</b>	65	65	65	65	65	65	65	65
2. Achieving the fund mean return of	9.10%	<b>9.09%</b>	8.64%	10.67%	10.08%	9.60%	9.76%	9.76%	8.38%	8.76%
3. Expected Bequest (Terminal Value at Death)	\$0	<b>\$0</b>	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
4. Expected Age at death of	83	<b>83</b>	83	83	83	83	83	83	83	83
5. No capacity to rely on age pension or additional income		<b>0</b>	0	0	0	0	0	0	0	0
6. Actual Terminal value at age 83 is	\$0	<b>-\$9,209</b>	-\$35,499	\$30,070	-\$9,038	\$19,241	\$36,847	\$115,777	-\$95,551	-\$2,730
7. Consumption inflation of	3%	<b>3%</b>	3%	3%	3%	3%	3%	3%	3%	3%
8. Annualised Standard Deviation of	5.20%	<b>5.19%</b>	3.56%	4.45%	5.10%	4.52%	6.21%	4.82%	4.95%	5.43%
9. Required Consumption to achieve bequest motive	-\$16,819	<b>-\$16,819</b>	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819
10 Age at which money runs out	83	<b>83.5</b>	82	85	83	84	85	88	81	83

	Baseline	AVERAGE OF ALL RUNS								
		1	34	35	36	37	38	39	40	41
1. Age at Retirement	65	65	65	65	65	65	65	65	65	65
2. Achieving the fund mean return of	9.10%	9.09%	8.38%	7.75%	9.64%	10.30%	10.07%	9.29%	7.12%	10.61%
3. Expected Bequest (Terminal Value at Death)	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
4. Expected Age at death of	83	83	83	83	83	83	83	83	83	83
5. No capacity to rely on age pension or additional income		0	0	0	0	0	0	0	0	0
6. Actual Terminal value at age 83 is	\$0	-\$9,209	-\$73,063	-\$90,509	\$61,098	\$12,887	-\$58,085	-\$50,995	-\$214,638	-\$63,739
7. Consumption inflation of	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
8. Annualised Standard Deviation of	5.20%	5.19%	6.32%	5.06%	5.71%	5.51%	5.29%	5.14%	4.38%	6.05%
9. Required Consumption to achieve bequest motive	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819
10 Age at which money runs out	83	83.5	81	80	86	84	82	82	77	82

	Baseline	AVERAGE OF ALL RUNS								
		1	42	43	44	45	46	47	48	49
1. Age at Retirement	65	65	65	65	65	65	65	65	65	65
2. Achieving the fund mean return of	9.10%	9.09%	8.95%	9.27%	9.18%	10.38%	9.59%	9.33%	8.28%	8.69%
3. Expected Bequest (Terminal Value at Death)	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
4. Expected Age at death of	83	83	83	83	83	83	83	83	83	83
5. No capacity to rely on age pension or additional income		0	0	0	0	0	0	0	0	0
6. Actual Terminal value at age 83 is	\$0	-\$9,209	-\$147,570	\$138,370	-\$26,564	\$39,283	\$74,198	\$131,102	\$26,356	-\$63,610
7. Consumption inflation of	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
8. Annualised Standard Deviation of	5.20%	5.19%	5.07%	4.62%	4.59%	4.73%	5.49%	6.21%	5.13%	4.36%
9. Required Consumption to achieve bequest motive	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819
10 Age at which money runs out	83	83.5	79	89	83	85	86	88	84	82



	Baseline	AVERAGE OF ALL RUNS	Run Number								
			1	50	51	52	53	54	55	56	57
1. Age at Retirement	65	<b>65</b>	65	65	65	65	65	65	65	65	65
2. Achieving the fund mean return of	9.10%	<b>9.09%</b>	9.42%	9.08%	9.11%	8.60%	8.27%	9.99%	8.79%	10.21%	
3. Expected Bequest (Terminal Value at Death)	\$0	<b>\$0</b>	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	
4. Expected Age at death of	83	<b>83</b>	83	83	83	83	83	83	83	83	
5. No capacity to rely on age pension or additional income		<b>0</b>	0	0	0	0	0	0	0	0	
6. Actual Terminal value at age 83 is	\$0	<b>-\$9,209</b>	\$78,794	-\$16,154	\$70,241	-\$4,998	\$6,908	\$90,810	-\$35,439	-\$166,149	
7. Consumption inflation of	3%	<b>3%</b>	3%	3%	3%	3%	3%	3%	3%	3%	
8. Annualised Standard Deviation of	5.20%	<b>5.19%</b>	4.82%	4.91%	4.04%	4.59%	5.32%	5.00%	6.10%	6.63%	
9. Required Consumption to achieve bequest motive	-\$16,819	<b>-\$16,819</b>	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	
10 Age at which money runs out	83	<b>83.5</b>	86	83	86	83	84	87	82	79	

	Baseline	AVERAGE OF ALL RUNS	Run Number								
			1	58	59	60	61	62	63	64	65
1. Age at Retirement	65	<b>65</b>	65	65	65	65	65	65	65	65	65
2. Achieving the fund mean return of	9.10%	<b>9.09%</b>	9.62%	9.98%	8.37%	8.73%	8.83%	8.10%	7.91%	10.10%	
3. Expected Bequest (Terminal Value at Death)	\$0	<b>\$0</b>	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	
4. Expected Age at death of	83	<b>83</b>	83	83	83	83	83	83	83	83	
5. No capacity to rely on age pension or additional income		<b>0</b>	0	0	0	0	0	0	0	0	
6. Actual Terminal value at age 83 is	\$0	<b>-\$9,209</b>	\$9,511	\$142,279	-\$5,836	-\$160,557	-\$141,891	-\$172,768	-\$87,206	\$75,924	
7. Consumption inflation of	3%	<b>3%</b>	3%	3%	3%	3%	3%	3%	3%	3%	
8. Annualised Standard Deviation of	5.20%	<b>5.19%</b>	4.98%	4.12%	5.36%	5.30%	4.04%	4.89%	3.95%	4.76%	
9. Required Consumption to achieve bequest motive	-\$16,819	<b>-\$16,819</b>	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	
10 Age at which money runs out	83	<b>83.5</b>	84	89	83	79	79	79	81	86	

	Baseline	AVERAGE OF ALL RUNS								
		1	66	67	68	69	70	71	72	73
1. Age at Retirement	65	<b>65</b>	65	65	65	65	65	65	65	65
2. Achieving the fund mean return of	9.10%	<b>9.09%</b>	8.70%	8.97%	9.94%	9.10%	9.57%	9.72%	8.74%	9.11%
3. Expected Bequest (Terminal Value at Death)	\$0	<b>\$0</b>	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
4. Expected Age at death of	83	<b>83</b>	83	83	83	83	83	83	83	83
5. No capacity to rely on age pension or additional income		<b>0</b>	0	0	0	0	0	0	0	0
6. Actual Terminal value at age 83 is	\$0	<b>-\$9,209</b>	-\$68,361	\$132,192	-\$114,771	-\$109,623	-\$22,925	-\$10,381	\$92,028	-\$8,772
7. Consumption inflation of	3%	<b>3%</b>	3%	3%	3%	3%	3%	3%	3%	3%
8. Annualised Standard Deviation of	5.20%	<b>5.19%</b>	5.01%	5.40%	4.57%	5.04%	5.16%	4.73%	5.23%	6.11%
9. Required Consumption to achieve bequest motive	-\$16,819	<b>-\$16,819</b>	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819
10 Age at which money runs out	83	<b>83.5</b>	81	88	80	80	83	83	87	83

	Baseline	AVERAGE OF ALL RUNS								
		1	74	75	76	77	78	79	80	81
1. Age at Retirement	65	<b>65</b>	65	65	65	65	65	65	65	65
2. Achieving the fund mean return of	9.10%	<b>9.09%</b>	9.16%	8.60%	8.63%	9.07%	9.47%	10.21%	8.44%	10.45%
3. Expected Bequest (Terminal Value at Death)	\$0	<b>\$0</b>	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
4. Expected Age at death of	83	<b>83</b>	83	83	83	83	83	83	83	83
5. No capacity to rely on age pension or additional income		<b>0</b>	0	0	0	0	0	0	0	0
6. Actual Terminal value at age 83 is	\$0	<b>-\$9,209</b>	\$37,058	\$177,355	-\$139,439	-\$25,858	-\$42,309	\$106,654	-\$37,861	\$211,065
7. Consumption inflation of	3%	<b>3%</b>	3%	3%	3%	3%	3%	3%	3%	3%
8. Annualised Standard Deviation of	5.20%	<b>5.19%</b>	6.30%	4.83%	6.12%	5.84%	5.99%	4.95%	6.37%	5.40%
9. Required Consumption to achieve bequest motive	-\$16,819	<b>-\$16,819</b>	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819
10 Age at which money runs out	83	<b>83.5</b>	85	90	79	83	82	88	82	94

	Baseline	AVERAGE OF ALL RUNS								
		1	82	83	84	85	86	87	88	89
1. Age at Retirement	65	<b>65</b>	65	65	65	65	65	65	65	65
2. Achieving the fund mean return of	9.10%	<b>9.09%</b>	8.32%	8.76%	7.91%	8.43%	9.67%	8.21%	8.85%	9.51%
3. Expected Bequest (Terminal Value at Death)	\$0	<b>\$0</b>	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
4. Expected Age at death of	83	<b>83</b>	83	83	83	83	83	83	83	83
5. No capacity to rely on age pension or additional income		<b>0</b>	0	0	0	0	0	0	0	0
6. Actual Terminal value at age 83 is	\$0	<b>-\$9,209</b>	-\$84,415	-\$112,349	-\$53,384	-\$39,530	\$43,438	-\$30,540	\$5,305	\$84,193
7. Consumption inflation of	3%	<b>3%</b>	3%	3%	3%	3%	3%	3%	3%	3%
8. Annualised Standard Deviation of	5.20%	<b>5.19%</b>	3.48%	5.64%	4.74%	5.17%	4.06%	4.60%	5.54%	6.25%
9. Required Consumption to achieve bequest motive	-\$16,819	<b>-\$16,819</b>	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819
10 Age at which money runs out	83	<b>83.5</b>	81	80	82	82	85	82	84	86

	Baseline	AVERAGE OF ALL RUNS								
		1	90	91	92	93	94	95	96	97
1. Age at Retirement	65	<b>65</b>	65	65	65	65	65	65	65	65
2. Achieving the fund mean return of	9.10%	<b>9.09%</b>	10.40%	10.07%	9.16%	9.88%	9.91%	9.62%	9.69%	8.63%
3. Expected Bequest (Terminal Value at Death)	\$0	<b>\$0</b>	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
4. Expected Age at death of	83	<b>83</b>	83	83	83	83	83	83	83	83
5. No capacity to rely on age pension or additional income		<b>0</b>	0	0	0	0	0	0	0	0
6. Actual Terminal value at age 83 is	\$0	<b>-\$9,209</b>	\$187,147	\$273,590	-\$181,761	-\$58,483	\$152,482	-\$139,754	\$97,362	-\$8,479
7. Consumption inflation of	3%	<b>3%</b>	3%	3%	3%	3%	3%	3%	3%	3%
8. Annualised Standard Deviation of	5.20%	<b>5.19%</b>	4.96%	5.33%	6.01%	5.31%	5.82%	5.70%	4.69%	5.70%
9. Required Consumption to achieve bequest motive	-\$16,819	<b>-\$16,819</b>	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819	-\$16,819
10 Age at which money runs out	83	<b>83.5</b>	92	95	79	82	89	80	87	83

	Baseline	AVERAGE OF ALL RUNS				
		1	98	99	100	101
1. Age at Retirement	65	<b>65</b>	65	65	65	65
2. Achieving the fund mean return of	9.10%	<b>9.09%</b>	8.75%	8.96%	7.44%	8.51%
3. Expected Bequest (Terminal Value at Death)	\$0	<b>\$0</b>	\$0	\$0	\$0	\$0
4. Expected Age at death of	83	<b>83</b>	83	83	83	83
5. No capacity to rely on age pension or additional income		<b>0</b>	0	0	0	0
6. Actual Terminal value at age 83 is	\$0	<b>-\$9,209</b>	-\$8,761	-\$13,804	-\$108,271	-\$148,111
7. Consumption inflation of	3%	<b>3%</b>	3%	3%	3%	3%
8. Annualised Standard Deviation of	5.20%	<b>5.19%</b>	4.84%	5.01%	6.09%	5.11%
9. Required Consumption to achieve bequest motive	-\$16,819	<b>-\$16,819</b>	-\$16,819	-\$16,819	-\$16,819	-\$16,819
10 Age at which money runs out	83	<b>83.5</b>	83	83	80	79

## Appendix 4: Summary of results of the Monte Carlo Simulation

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	Age	Numbers at age, who have sufficient funds
	Age less than 100	0
	Age less than 99	0
	Age less than 98	0
	Age less than 97	0
	Age less than 96	0
	Age less than 95	1
	Age less than 94	2
	Age less than 93	3
	Age less than 92	4
	Age less than 91	4
	Age less than 90	5
	Age less than 89	8
	Age less than 88	12
	Age less than 87	17
	Age less than 86	24
	Age less than 85	35
	Age less than 84	42
	Age less than 83	55
	Age less than 82	70
	Age less than 81	78
	Age less than 80	86
	Age less than 79	97
	Age less than 78	98
	Age less than 77	100
	Age less than 76	100
	Age less than 75	100
	Age less than 74	100
	Age less than 73	100
	Age less than 72	100
	Age less than 71	100
	Age less than 70	100
	Age less than 69	100
	Age less than 68	100
	Age less than 67	100
	Age less than 66	100
	Age less than 65	100

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