The sequencing risk threat to retirement adequacy from increased superannuation contributions

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Abstract

The Commonwealth Government of Australia has embarked on a policy of increasing the legislated minimum and compulsory provision of retirement savings for employees (known as the Superannuation Guarantee, SG) from 9% to 12% of salary. Using a simulation approach, we find that retirement adequacy generally improves under the increased SG provision, particularly if a relatively favorable sequence of returns is experienced over the plan member's working life. However, the increased SG fails to ameliorate low income replacement ratios for those who experience an unfavorable sequence of returns. Using a variety of default option designs, we show that increasing the contributions of workers without appropriately altering the asset allocation strategy of such investments may expose workers to greater sequencing risk, potentially undermining the objectives of the contribution increase. We find that a combination of increased SG and a dynamic lifecycle approach to default design achieves superior retirement outcomes for plan members.

Keywords: superannuation, DC plans, retirement adequacy, sequencing risk, contributions, asset allocation

JEL Codes: G11, G23, G28

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Abstract

The Commonwealth Government of Australia has embarked on a policy of increasing the legislated minimum and compulsory provision of retirement savings for employees (known as the Superannuation Guarantee, SG) from 9% to 12% of salary. Using a simulation approach, we find that retirement adequacy generally improves under the increased SG provision, particularly if a relatively favorable sequence of returns is experienced over the plan member's working life. However, the increased SG fails to ameliorate low income replacement ratios for those who experience an unfavorable sequence of returns. Using a variety of default option designs, we show that increasing the contributions of workers without appropriately altering the asset allocation strategy of such investments may expose workers to greater sequencing risk, potentially undermining the objectives of the contribution increase. We find that a combination of increased SG and a dynamic lifecycle approach to default design achieves superior retirement outcomes for plan members.

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1. Introduction

In 1992 the Commonwealth Government of Australia introduced a mandated system of retirement savings based on hard compulsion, known as the Superannuation Guarantee (SG). Under the SG, employers are required to make tax-deductible superannuation contributions for their employees. Despite being a relatively inclusive and comprehensive retirement savings system, serious concerns over the retirement adequacy of Australian workers remain. In an effort to combat the pension liability of an ageing population, exacerbated by increased life expectancy and rising health care costs, in 2012 the Commonwealth Government of Australia proposed to gradually increase the SG from 9% to 12% over a 10-year period. This is expected to result in a greater proportion of workers in the future exiting the workforce with adequate financial resources to fund their retirement.

While simply increasing the compulsory level of savings may seem like a straightforward solution to improving retirement adequacy, added contributions are not costless. The major risk facing workers is an unfavorable sequence of returns in the years immediately prior to retirement. Unfavorable path dependency of portfolio returns, known as 'sequencing risk,' has its origins in constant proportion portfolio insurance (CPPI) theory (Black and Perold, 1992) and has become recognized as the key risk facing the retirement portfolios of workers. The effect of sequencing risk increases with the size of the retirement savings portfolio and for most workers this risk is greatest in the decade immediately prior to retirement. Coupled with a suboptimal asset allocation strategy, the sequencing risk exposure of a larger portfolio represents a significant risk to the retirement portfolio of most workers. In this study we show that increasing the SG provision is not a straightforward solution to improving retirement adequacy.

We use long horizon historical returns data from various asset classes to simulate retirement adequacy outcomes of workers investing in typical asset allocation strategies. In contrast to using a single rate of return on retirement savings to model a single wealth outcome at retirement (Bateman and Piggot, 1993), we use Monte Carlo, bootstrap simulation and stationary bootstrap simulation techniques to model accumulation paths based on historical returns to derive a distribution of terminal wealth outcomes. We consider the success (or otherwise) under the revised SG provisions using the retirement wealth ratio (RWR) and the associated income replacement rate (RR).

The simulation results show that increasing the contributions of workers without appropriately altering the asset allocation strategy of such investments will expose workers to greater sequencing risk, and potentially undermine the objectives of the pension increase. In particular, asset allocation strategies with a higher proportion of stocks are shown to be more suitable for achieving adequate retirement outcomes for workers invested in the 'default' superannuation asset allocation option, which is thus an extension of the findings of Samuelson (1994). To counter the increased sequencing risk experienced by workers contributing a greater proportion to superannuation under revised SG provisions, we examine the effectiveness of competing asset allocation styles within the default option to offset sequencing risk. Despite the higher volatility experienced in the portfolio, we find that increasing the allocation to stocks actually reduces the risk of workers experiencing adverse retirement outcomes in the accumulation phase of defined contribution (DC) superannuation plans.

2. Retirement adequacy and superannuation policy

Retirement policy in Australia was designed as a three-pillar system; the age pension, the SG and voluntary retirement savings (Piggott et al., 2001). For the majority of workers, mandatory contributions under the second pillar are seen as the critical component aimed at reducing the government dependency of future retirement benefits. Under the superannuation reforms in Australia in 2011/12, collectively known as the Stronger Super reforms, employers must only pay mandated contributions to low management expense ratio (MER) products with a single investment option. These low cost default funds are officially authorized as 'MySuper' products. The majority of workers do not deviate from the employer default fund (Commonwealth Treasury, 2013) and, although the reforms acknowledge the importance of the default asset allocation strategy, the SG does not mandate a retirement income scheme, only an accumulation profile. Superannuation funds are not directly rewarded for maximizing the terminal wealth of their members or ensuring that the level of wealth is 'adequate' for retirement.

Defining a level of wealth that is deemed 'adequate' is not simple. Since the retirement adequacy for most retirees depends on their desired lifestyle during retirement, a number of criteria need to be met. To better define adequacy, some scholars employ a preference-based calibration approach that uses constant relative risk aversion utility or constant absolute risk aversion utility to define retirement adequacy (Hurd and Rohwedder, 2003; Scholz et al., 2004; Poterba, et al. 2006). These have had very limited success.

A number of competing measures of retirement adequacy are based on terminal wealth. Terminal wealth is easy to operationalize and it enables analysis of retirement outcomes using a range of evaluation criteria. More importantly, it also represents the single most important objective that workers seek to maximize before converting terminal wealth into an annual retirement income. An alternative but related measure of retirement adequacy is the income replacement rate (RR). The RR provides a target that is expressed as the annuity equivalent value as a fraction of a person's salary in their final year of employment. This measure is popular in the literature because it is very likely that people's post-retirement expectations are closely linked to their pre-retirement income (Palmer, 1994; Moore and Mitchell, 1997). An income replacement rate of 65-75% is commonly assumed for Australian workers (Cooper, 2010) and is comparable to international rates (Binswanger and Schunk, 2012). Also derived from terminal wealth is the retirement wealth ratio (RWR) which is a useful measure of adequacy because it frames the retirement target as the multiple of terminal wealth to final annual salary (Booth and Yakoubov, 2000). These benchmarks are accessible to the individual because they more easily relate their retirement savings to their standard of living.

2.1 Portfolio size effect, sequencing risk and asset allocation

Of great concern among workers in the accumulation phase of DC superannuation plans prior to retirement is the portfolio size effect and the related phenomenon of sequencing risk. In the early years of workers' retirement savings plan, contributions account for the majority of the portfolio. However, as the returns on past contributions accumulate to become the main driver of terminal wealth, incremental contributions become less important. The relationship between contributions and returns over time is the source of the portfolio size effect which has been explored in Basu and Drew (2009a).

Sequencing risk is the risk of experiencing returns in an unfavorable order during periods in which there are capital changes to the portfolio (Basu et al., 2012). Conversely, a favorable sequence of returns can result in ‘good’ sequencing risk (Frank and Blanchett, 2010; Frank et al. 2011; Doran et al. 2012). Sequencing risk is highly relevant to the issue of retirement adequacy because a large market downturn occurring close to retirement could deplete workers’ retirement nest-egg to the point where it may never recover (Doran et al. 2012).

Modern portfolio theory (MPT) assumes that wealth is a function of a series of time-weighted returns (Markowitz, 1952). This only holds in the rare case of an initial endowment with no subsequent changes in capital. The presence of continual contributions and withdrawals to and from a retirement savings plan is a major determinant of workers’ wealth. This forms a set of dollar-weighted returns which can be equated with the investment’s internal rate of return (IRR). Dollar-weighted returns are intuitive to many workers but the concept rarely appears as a performance objective in portfolio management. MPT ignores the sequence of returns which can substantially affect the terminal wealth of a retirement portfolio (Basu et al., 2012). The ability of superannuation portfolios to achieve a dollar-weighted return target relies heavily on both the allocation of assets within the portfolio and changes in asset allocation through workers’ lives.

2.2 Default asset allocation plans

Default investment options that maintain a constant proportion of asset classes, known as target risk funds (TRF), assume that workers have an infinite investment horizon and maintain complete flexibility over their retirement date. Target risk funds (TRFs) maintain the same level of risk through time by holding a constant proportion of growth and defensive assets. TRFs are commonly employed in MySuper products at varying proportions of growth and defensive assets. TRF strategies can range from 100% stocks to 100% cash strategy. In addition to these two extremes, in this study we consider growth/defensive asset splits of 50/50 (moderate TRF portfolio), 60/40 (default option average (DOA) TRF portfolio) and 70/30 (balanced TRF portfolio).

Since workers generally have a finite investment horizon, target date funds (TDF) have since emerged. TDFs switch from growth to defensive assets according to a pre-determined glide-path as a worker approaches retirement. TDFs reduce the proportion of growth assets in the retirement portfolio as the worker approaches a retirement date using deterministic switching rules. TDFs have become a core product for investors saving for retirement, particularly in the US (Estrada, 2013). But while lifecycle strategies implied in TDFs attempt to address the issue of a finite investment horizon, they are unable to appropriately position workers' retirement investments towards a defined adequacy target (Basu et al., 2011). In the case of deterministic asset allocation strategies such as TRFs and TDFs, the asset allocation strategy may become inconsistent with the investment objective over time without corrective action.

Portfolio adequacy based on a defined terminal wealth target however can be better achieved by using target-driven asset allocation strategies such as a dynamic lifecycle strategy (DLC) strategy. The DLC strategy increases the allocation to riskier asset classes when workers' portfolio wealth is less than a defined adequacy target. The glide-path of a DLC strategy is not pre-determined because the asset allocation policy is not only dependent on a worker's retirement date but also on the performance of the portfolio relative to a retirement target. When the portfolio wealth is greater than an adequacy target the allocation shifts towards more defensive assets, and when wealth falls below the target the portfolio shifts its weight towards growth assets. The DLC strategy is a flexible approach that preserves terminal wealth as the primary objective, particularly in the presence of sequencing risk. This approach is in sharp contrast to the static and deterministic allocation strategies of TRFs and TDFs that subordinate terminal wealth to a secondary aim behind maintaining a pre-determined policy portfolio.

We propose that simply increasing the SG provision alone may not improve retirement adequacy for DC plan members. But increasing the SG contribution rate, coupled with a flexible asset allocation mechanism that maintains a terminal wealth target as its objective, can adequately overcome sequencing risk exposure. Using a suite of robust simulation approaches we consider the practical implications of an increase in the SG contribution rate and its impact on retirement adequacy.

3. Methodology and data

The model used to generate terminal wealth outcomes is

$$TW = k \sum_{t=0}^{n-1} S_t(1 + r_t) \prod_{u=t+1}^{n-1}(1 + r_u), \quad (1)$$

where TW is the terminal value of retirement wealth, k is the plan contribution rate, r_t is the nominal rate of investment return earned in year t and r_u is the nominal rate of return in year $t-1$, n is the number of years before retirement and S_t is the annual salary in year t and is given by $S_t = S_0(1+g)^{t-1}$ where S_0 is the starting salary and g is the nominal salary growth rate. From (1) it is clear that the contribution rate, investment horizon and asset allocation are the three main factors affecting retirement adequacy. While the investment horizon critically impacts on a worker's retirement adequacy, we exclude its impact in this analysis because few workers have much flexibility in choosing their retirement date. Analyzing the effect of investment horizon on portfolio outcomes has been considered in other analyses (Hickman, et al. 2001) but for model tractability we maintain a constant investment horizon.

For the simulation we use a monthly contribution model in line with the SG provisions that mandate at least a quarterly contribution frequency. We examine two competing SG contribution rate scenarios: the old minimum rate of 9% and the new minimum rate of 12%. These rates are kept constant over the entire investment horizon so as to compare outcomes under each contribution regime. We also assume that the employee is fully employed during the entire investment horizon and hence contributions will be a constant percentage of salary over time. Table 2 outlines the basic simulation model inputs.

Table 1 here

We examine seven asset allocations: the five target risk funds (TRFs) outlined earlier; one target date fund (TDF); and, one dynamic lifecycle fund (DLF). The following asset allocation assumptions were made. A 5% allocation to Australian T-bills is always maintained if an asset allocation strategy is invested in defensive assets, except for the 100% cash strategy. The remaining proportion of any allocation to defensive assets is made to Australian bonds. Where an asset allocation strategy is invested in growth assets, half of the proportion of growth assets is allocated to Australian stocks and half is allocated to U.S. stocks.

TDFs have deterministic glidepaths. The asset class proportions depend only on the worker's retirement age and the glide-path algorithm. We consider one TDF strategy that invests 80% in growth assets and 20% in defensive assets for the first 20 years of the investment period. In the 21^{st} year the strategy commences a linear switch from growth to defensive assets so that by the end of the 40-year investment horizon the portfolio has invested 56% in growth assets and 44% in defensive assets. This glide-path is a reasonable representation of the TDF strategies employed by funds.

The DLC strategy is partitioned into three investment periods. For the first 30 years the strategy invests in growth assets only so that Australian stocks and U.S. stocks each comprise half of the portfolio. The rationale for the initial allocation to growth assets only is that the objective of the worker is to maximize wealth over the first 30 years of their investment horizon. Consistent with lifecycle theory, the worker should have sufficient time to recover wealth in the final ten years if stock market performances have been unfavorable. The remaining two partitions are each five years in length and have slightly different asset allocation rules. For both partitions, the below-target portfolio is 100% in growth assets. The above-target portfolio in the second partition is 80% in growth assets and 20% in defensive assets. The above-target portfolio in the third and final partition is 60% in growth assets and 40% in defensive assets. The rationale for the decreasing proportion of growth assets in the above-target portfolios in each of the final two partitions is to reduce risk when the worker approaches retirement, so long as the worker remains above this target. Unlike the TDF strategy, the DLC strategy uses performance feedback to control the asset allocation at any point in time.

3.1 Data

We use monthly return data of four asset classes obtained from the Global Financial Database. Nominal returns, including periodic cash flows such as dividends, for Australian Stocks, U.S. Stocks, Australian Bonds and Australian T-bills from October 1882 to February 2013 are used as the basis for the simulation.

The Global Financial Database adjusts returns data for survivorship bias. The use of monthly returns in this study replicates the monthly contribution frequency typical for most workers who contribute to a superannuation plan. We recognize the issue of the purchasing power of a plan member's retirement savings through the use of the retirement wealth ratio (RWR), which anchors terminal wealth to the price level of the year in which the plan member receives their final salary. We use Australian stocks and U.S. stocks as proxies for growth assets and Australian bonds and Australian T-bills as proxies for defensive assets. While an international fixed interest asset class may comprise a portion retirement products in practice, we exclude them based on the reasoning that the majority of bond investments in MySuper products are domestic (Morningstar, 2013). Descriptive statistics of the returns data for each of the four asset classes used in this study are presented in Table 2.

Table 2 here

3.2 Simulation

We model using both parametric and non-parametric simulation methods to generate 10,000 accumulation paths for each asset allocation from historical data. We selected three simulation methods to test for the robustness of results – Monte Carlo, standard bootstrap and stationary bootstrap.

First, the Monte Carlo simulation draws returns from a normal distribution with a mean and standard deviation calibrated to the historical data. Although the Monte Carlo method is a versatile simulation technique, it assumes returns are Gaussian, it departs from the time characteristics of the historical data, and it fails to maintain cross-correlation between asset classes.

Second, the standard bootstrap process randomly resamples row vectors with replacement (Efron, 1979). This process generates 10,000 simulated 480-month long return paths from the underlying data series. This approach does not impose distributional assumptions and maintains historical cross-correlations between asset classes. It does not however preserve the time series characteristics of the data.

Third, we use the stationary bootstrap proposed by Politis and Romano (1994). This is similar to the Efron (1979) bootstrap in the sense that it does not impose distributional assumptions on the data. It also retains cross-correlations between the returns of different asset classes and incorporates the time series characteristics of the data by resampling blocks of returns. The block length is randomly sampled from a geometric distribution and is based on the original block bootstrap method introduced by Kunsch (1989). In the absence of a random block length this method requires the arbitrary specification of a fixed block length in practical settings (Bühlmann, 2002). This simulation method is stationary because, by statistical inference, a moving block length permits the synthetic time series to be stationary however this is conditional on the underlying data being stationary as well. This feature allows the simulation to retain some of the serial dependence in the data while still generating the synthetic time series needed for our analysis.

3.3 Terminal wealth evaluation criteria

We set the investment objective RWR target (RWR_{target}) based on a nominal return target of 7% per annum. This is based on a typical superannuation fund objective of the average inflation rate (represented by the consumer price index (CPI)) plus 400bps. Target returns that are too high or too low are unsuitable for use in DLC strategies because the dynamic switching capability is compromised. Under the 9% contribution profile, the RWR_{target} that is equivalent to the compounded accumulation of a fund achieving a 7% annual return over the investment horizon is 6.95 times final salary. Under the 12% contribution profile, the RWR_{target} is 9.27 times final salary. The use of a common return target adjusts for different expected levels of terminal wealth because of different contribution levels.

While standard deviation is a useful measure of variability, for RWR we use the lower partial moment (LPM) which represents downside risk for different levels of risk aversion (Bawa, 1975; Fishburn, 1977). The LPM is given by:

$$LPM_{\lambda} = \frac{1}{n}\sum_{t-1}^{n} Max[0, (RWR_{target} - RWR_{T})]^{\lambda}, \tag{2}$$

where RWR_{target} is the target outcome (determined above), RWR_t is the outcome for the *t*-th observation, *n* is the number of observed RWR model outcomes and λ is a parameter representing the order of the LPM, which can be calibrated to the risk aversion of the participant. The three LPM orders considered in this analysis are the probability of falling short of the RWR_{target} (LPM_{FS}), the magnitude of the shortfall below RWR_{target} (LPM_{MS}) and the below-RWR_{target} semi-variance (LPM_{SV}).

We also use the Sortino ratio which is a reward-to-risk measure that does not penalize performance for volatility above the target outcome (Sortino and Price, 1994). The Sortino ratio is given by:

$$Sortino\ Ratio = \frac{\overline{RWR}_T - RWR_{target}}{[LPM_2]^{1/2}}, \tag{3}$$

where $\overline{RWR}_T$ is the mean RWR, RWR_{target} is the target outcome and LPM_2 is the second lower partial moment as defined above. An extension of this measure is the upside potential ratio (UPR) which combines upside potential and downside risk (Sortino et al. 1999) and is given by:

$$UPR = \frac{\frac{1}{n}\sum_{t-1}^{n} Max[0,(RWR_T - RWR_{target})]}{[LPM_2]^{1/2}}. \tag{4}$$

The numerator is the first upper partial moment and the denominator is the second lower partial moment using RWR_{target}. This measure allows us to consider the above-RWR_{target} outcomes adjusted for downside risk.

4. Results

We conducted the simulations using all three methods as discussed above. However in the following results we focus only on the stationary bootstrap method for brevity. Of the three methods, we select the stationary bootstrap because Politis and Romano (1994) show that this technique, where the block size is random, is less sensitive to block size misspecification when compared to competing methods. The full set of results for all simulations is presented at the Appendix.

4.1 RWR distributions

The distribution of retirement outcomes must be considered when investigating retirement adequacy, not just average outcomes. Table 3 presents the distributional statistics of the RWR for a 9% and 12% SG contribution rate. The median adequacy shows that, as expected, increasing contributions by one-third results in a one-third increase in the median RWR. This is equivalent to an additional nominal AEV of $211,000. Terminal wealth has increased by 4.15 times final salary which equates to about $1.124m in nominal terms. Considering those outcomes in the tails of the RWR distributions, in addition to the central outcomes, provide more insight into what increasing the SG provision means for plan members in terms of potential retirement outcomes. These results are in line with those of Bateman and Piggot (1993).

Increasing the SG contribution rate increases the mean, median and range of the RWR distribution. While there is a substantial increase in the maximum RWR in absolute terms, the impact of the increasing contribution rate is less substantial. For RWR outcomes on the lower end of the distribution, the absolute increase in retirement outcomes is more modest. Using an RWR of 10 (the 65% RR equivalent) as a benchmark is useful for comparison, it is evident that the 25th percentile has been shifted above this level. Overall it appears that increasing the SG contribution rate is effective in boosting many plan members above this adequacy threshold. Based on this finding, we reject the hypothesis that increasing the contribution rate from 9% to 12% has no impact upon the retirement adequacy of workers' solely contributing to a superannuation fund. Note that, theoretically, the results in the following tables should differ by a scale factor of 1.33 (12% / 9%). However the pseudo-time series generated by the stationary bootstrap approach will generate a minor divergence from the theoretical scale due to sampling from the resulting approximated geometric distribution.

Table 3 here

Table 4 shows that the one-third increase in the contribution rate is accompanied by a corresponding increase in the standard deviation of retirement outcomes. This equates with the expected outcome. However raising the SG contribution rate, without appropriately adjusting asset allocation, also magnifies the exposure to sequencing risk. To understand the real exposure to sequencing risk Table 4 presents the lower partial moments for the 9% and 12% contribution rates using a balanced asset allocation.

Table 4 here

Table 4 shows that the increased risk associated with increasing the SG contribution rate is very relevant to the issue of retirement adequacy. Each measure of downside risk, relative to the appropriate targets, has increased as a result of increasing the contribution rate. Workers are 5% more likely to fall short of the retirement target, albeit a higher target, and the expected value of this shortfall has increased by 44%. The below target semi-variance has doubled indicating that workers are twice as exposed to downside sequencing risk. The increased risk relative to the retirement target is not entirely offset by the upside risk. The *UPR* has declined by 10% under the higher contribution rate which confirms that simply increasing the SG contribution rate does not necessarily improve the retirement adequacy of workers.

It appears that the improvements in retirement adequacy come at the cost of increased sequencing risk borne by workers. So the asset allocation becomes of even greater importance to workers' retirement portfolios. Workers who contribute 12% invest significantly more over the accumulation phase and any gains made to the portfolio largely evaporate during the critical last decade before retirement. But if returns on the retirement portfolio dwarf the value of additional contributions, then perhaps the asset allocation that governs those returns can be altered to achieve retirement adequacy?

4.2 Changing the asset allocation

Table 5 shows that different asset allocations can produce widely different median retirement outcomes. The asset allocation of the default option has a substantial impact on retirement adequacy in regards to median outcomes. Asset allocations with a higher proportion of growth assets result in higher adequacy measures on average.

Table 5 here

Like increasing the SG contribution rate, median retirement outcomes improve where workers' retirement portfolios are comprised of a higher proportion of stocks. This suggests that TRFs tilted toward stocks may lead to more adequate retirement outcomes. The TDF strategy results in a similar median retirement outcome to the balanced TRF indicating that a deterministic glidepath does not materially improve retirement outcomes. The DLC strategy, however, is more successful. The DLC strategy produces the highest median adequacy measures with a median RWR and RR of 15.26 times and 97% respectively indicating that a higher allocation to stocks combined with dynamic switching rules offers a significant improvement. The distributional statistics of the RWR retirement outcomes are presented in Table 6 for the seven asset allocations.

Table 6 here

Figure 1 here

The boxplot in Figure 1 shows that the TDF strategy has a very similar RWR distribution to the balanced TRF. This supports the conclusion that deterministic switching rules on their own fail to improve retirement adequacy metrics. Besides the 100% stocks strategy, the DLC strategy has the highest maximum, 75th percentile, median and 25th percentile outcomes. The minimum outcomes for the 100% stocks and the DLC strategy are the lowest of the seven strategies, except for the 100% cash strategy but the difference between minimums when compared to more conservative strategies appears negligible. The minimum outcomes are so far below the adequacy guideline of a RWR of 10 that this small improvement from implementing a more defensive strategy is not worth the limited upside.

We further found that TRFs tilted toward growth assets naturally achieve better retirement outcomes. But the higher allocation of growth assets also exposes the plan member to greater volatility. Table 7 shows that the standard deviation is higher for strategies with a higher growth asset allocation but this is contrasted with the LPM metrics that appropriately account for downside risk. There is a clear inverse relationship between the LPM results and the allocation to growth assets. The terminal wealth outcomes for the balanced TRF and the TDF asset allocation are not substantially different. Both asset allocations have similar accumulation paths for the first 20 years of the investment horizon where contributions are still a major part of the total portfolio. Although the TDF begins to switch toward defensive assets after this point, it is not until age 55 that the balanced TRF and the TDF hold the exact same proportion of growth and defensive assets. This is also the point where the portfolio size effect means that contributions are accounting for about one-fifth of the total portfolio value.

Table 7 here

However the higher returns associated with growth assets mean that the returns are compounding faster using a DLC asset allocation strategy. While the higher proportion of growth assets results in improved performance for the DLC strategy dynamic switching rules also play their part. Table 7 shows that the DLC strategy experiences a higher standard deviation but that LPM measures are substantially better. The shortfall probability (LPM_{FS}) is less than 4% for the DLC strategy which is the lowest shortfall probability of all seven asset allocations. The DLC strategy also has the lowest magnitude of shortfall and below-target semi-variance of all seven asset allocations and is superior to the balanced TRF when comparing the Sortino ratio and *UPR*.

5. Discussion

5.1 Heat maps of the retirement risk zone

We examine the simulation results in the final decade of the accumulation phase using heat maps. For ease of interpretation, we use granular shading to examine the monthly RWR relative to the adequacy target RWR_{target} of 6.95. Figure 2 depicts the heat map for the balanced TRF (70/30), Figure 3 depicts the heat map for the TDF and Figure 4 depicts the heat map for the DLC strategy.

The diagrams show how each asset allocation strategy pilots the superannuation portfolio towards the retirement date. The retirement risk zone (RRZ) represents the decade immediately prior to retirement. In the RRZ returns account for about 80% of the portfolio value. Figure 2 shows that the balanced TRF strategy achieves the adequacy target in four out of 49 paths prior to the RRZ. But overall, the majority of paths eventually achieve adequacy at retirement.

Despite it taking longer for some paths to achieve adequacy, the TDF strategy in Figure 3 demonstrates similar adequacy outcomes. The TDF strategy has eight paths that have achieved adequacy upon entering the RRZ however, there seems to be a larger proportion of paths below the adequacy target during the initial months. A common attribute of both the balanced TRF and the TDF strategies is that the retirement savings plans suddenly achieve (or fall behind) the adequacy target. It is not uncommon for a yellow cell to turn into a green cell (or vice versa) within a single month.

Figure 2 here

Figure 3 here

Figure 4 here

But the transition from inadequate savings to adequate savings is much smoother under the DLC strategy as shown in Figure 4. Unlike the balanced TRF and TDF strategies, the results show that it is very unlikely that a path will fall behind the adequacy target once it has been achieved. Moreover, a higher proportion of paths are already above the adequacy target upon entering the RRZ, attributable to the higher allocation to stocks in the earlier years of the accumulation phase. Figure 4 also shows that the dynamic switching rules assist several paths in achieving the adequacy during the critical RRZ.

5.2 Scenario analysis – left tail outcomes

The value at risk (VaR) and expected tail loss (ETL) retirement outcomes for each asset allocation strategy under the 9% and 12% SG provision are given in Table 8. As expected, increasing the SG provision produces a commensurate increase in the tail related risk measures for each asset allocation strategy. But both the VaR and ETL measures are higher for equity driven strategies including the 100% stocks TRF and the DLC strategy. This result challenges the traditional notion that suggests stocks may achieve adverse outcomes due to the higher observed volatility. An equity driven strategy actually reduces the risk of workers' experiencing a lower adverse retirement outcome.

Table 8 here

The VaR measures for the 9% and 12% SG contribution rate highlight the importance of the asset allocation strategy used in the default option. For instance, the VaR for a 9% SG contribution using a DLC strategy is similar to the VaR for 12% SG contribution rate using a TRF strategy. Increasing the SG provision may not be of much benefit to some workers if the asset allocation strategy chosen by the default option is inefficient.

To highlight this effect we examine two scenarios that both experience an unfortunate sequence of returns over the investment period. Scenario 1 uses a DLC asset allocation strategy with a 9% SG contribution rate. Scenario 2 uses a TRF asset allocation strategy with a 12% SG contribution rate. These are retirement outcomes on the left tails of the two RWR distributions. Figure 5 presents the accumulation paths.

Both scenarios experience similar retirement outcomes. The additional contributions made in Scenario 2 did not create more wealth for retirement compared to Scenario 1. The moderate TRF coasts toward the retirement outcome without any consideration of a retirement target of 9.37 times final salary. This results in a substantial shortfall. In two instances, the dynamic switching rules of the DLC strategy assisted in its pursuit of its lower retirement target of 6.95 times by maintaining or increasing the exposure to growth assets. The first occurs directly after the worker turns 55 years of age and the second occurs after a market downturn shortly before retirement. Recall that the appropriate retirement target is lower for a 9% SG provision than a 12% SG provision because less contributions are invested resulting a lower expected target. The worker is thus able to achieve the appropriate retirement target associated with a 9% contribution rate. While the use of only two sample paths in this example does not prove our hypothesis, it does demonstrate how a dynamic strategy successfully aims for a target wealth outcome while more static strategies may comply with their asset allocation objectives yet underperform intended wealth outcomes.

Figure 5 here

An appropriate measure for evaluating investment outcomes with multiple cash flows, such as those associated with defined contribution plans (DC plans), is the dollar-weighted return or internal rate of return (IRR) (Dichev and Yu, 2011). Table 9 presents the IRR outputs from the above scenario analysis alongside the geometric return and average return for comparison. Being time-weighted, both the geometric return and the arithmetic average return are inappropriate for evaluating terminal wealth outcomes in the presence of cash flows such as contributions (Basu et al., 2012) because they overstate the return associated with each accumulation path. The sequence of returns was worse for the worker in Scenario 1 as the difference between the IRR and geometric return is larger.

Table 9 here

Table 9 shows that both scenarios accumulated similar levels of wealth during the worker's life and both produce the same terminal RWR. But the IRR for Scenario 1 is significantly higher than Scenario 2. Scenario 1 outperforms Scenario 2 for workers who experience unfavorable market conditions during the accumulation phase, but at a higher risk as measured by the standard deviation. Standard deviation (as a variability metric) is a poor measure of retirement risk because the worker in Scenario 2 has contributed an additional $160,000 to simply experience a smoother accumulation path.

6. Concluding remarks

Using a simulation methodology, we find that the impact of increasing the SG from 9% to 12% for defined contribution plans is to increase retirement adequacy in expectation only. A large proportion of modelled retirement outcomes exceed the retirement adequacy threshold. Increasing the mandatory contribution rate has a positive impact on the retirement adequacy of workers. But retirement outcomes from increased contributions observed in the left tail of the distribution make no substantial difference in absolute terms. The full distribution of potential retirement outcomes should thus be considered rather than central measures only.

Increasing the SG provision is therefore not a straightforward solution to improving retirement adequacy. An increase in contributions translates into workers being exposed to greater sequencing risk as the size of their superannuation portfolio grows, particularly when coupled with a static asset allocation strategy. Indeed the downside risk relative to a target appropriate for the level of contributions nearly doubles.

Using a stationary bootstrap simulation method, we find that the impact on retirement adequacy of changes in the portfolio asset allocation depends largely on the proportion of growth assets in the portfolio. TRFs with a higher proportion of stocks produce significantly better retirement outcomes and also experience less retirement inadequacy retirement exposures despite the higher risk associated with stocks.

Target date funds (TDF) and dynamic lifecycle (DLC) strategies that change the proportion of growth and defensive assets during the investment horizon also support this result. A TDF strategy with exposure to stocks in a similar proportion to the balanced TRF produces similar retirement outcomes. The DLC strategy with a higher proportion of stocks produced substantially better retirement outcomes than the balanced TRF, mainly due to the capacity to dynamically switch allocations during the accumulation phase. We also showed that the downside risk relative to an adequacy target was lower for the DLC strategy than for any other strategy. We have shown that increasing the contribution rate for a portfolio with a static asset allocation strategy merely generates a smoother profile towards an adequacy target. The same result may be achieved at a lower contribution rate coupled with a dynamic strategy that accounts for sequencing risk exposure during the accumulation phase. The results demonstrate that generating adequate income for workers in retirement should be the key motivation behind designing retirement savings solutions, instead of using simple performance targets pegged to annual returns and portfolio standard deviation.

We acknowledge that there are several limitations to this study. First, retirement adequacy can be partially or fully met by the age pension and voluntary superannuation savings. Our analysis is confined to retirement adequacy under the SG regime only. Second, workers' retirement wealth ratio (RWR) may be different from those computed here due to wealth external to the superannuation system. Third, we assumed a constant investment horizon of 40 years and clearly a different investment horizon may yield different outcomes. A shorter investment horizon may require a different default investment option to the ones we considered which might be more effective in meeting retirement adequacy. Finally, we abstracted from taxes and inflation in this analysis, both of which are important factors affecting retirement adequacy.

There is scope for further research on variations of this DLC strategy. Further refinements, including more flexible switching rules, could make the strategy more applicable for retirement savings in practice. More sophisticated dynamic strategy algorithms are also an obvious area for future research.

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Tables

Input	Value
Starting balance	$0
Age entering workforce	25
Age at retirement	65
Investment horizon	40
Starting salary	$55,000
Salary growth rate	4%

Table 1: The hypothetical worker wage profile and investment period.

	Australian Stocks	U.S. Stocks	Australian Bonds	Australian T-bills
Median (%)	1.11 (13.2)	0.86 (10.32)	0.36 (4.32)	0.28 (3.36)
Mean (%)	1.02 (12.24)	0.88 (10.56)	0.50 (6.00)	0.35 (4.20)
Standard Deviation (%)	3.77 (45.24)	5.10 (61.2)	2.28 (27.36)	0.29 (3.48)
Skewness	-0.84	1.01	0.59	1.77
Kurtosis	13.98	11.67	13.65	3.14
Range (%)	65.30	72.16	34.93	1.55
Minimum (%)	-42.13	-23.63	-13.47	0.06
Maximum (%)	23.16	48.53	21.47	1.62
Jarque-Bera test statistic	1,2837	9,080	12,160	1,459

Table 2: Descriptive statisitcs of monthly returns data for the Australian stocks, U.S. stocks, Australian bonds and Australian T-bills. The median, mean and standard deviation include annualised figures in brackets.

SG	Min	P25	Median	Mean	P75	Max	IQRR
9%	2.81	9.19	12.32	14.60	17.50	126.52	0.67
12%	3.60	12.14	16.47	19.32	22.94	156.68	0.66

Table 3: Distributional statistics for changes to the Superannuation Guarantee (SG) from a 9% contribution rate to a 12% contribution rate using a balanced TRF asset allocation. The IQRR refers to the interquartile range ratio using a stationary bootstrap simulation.

Contribution Rate	*σ (RWR)*	LPM_{FS}	LPM_{MS}	LPM_{SV}	*UPR*
9%	8.32	0.0792	0.0779	0.1219	22.1447
12%	11.10	0.0835	0.1123	0.2426	20.6258
Percentage Increase	**33%**	**5%**	**44%**	**99%**	**-7%**

Table 4: Standard deviation of RWR, lower partial moments and upside potential ratio for the 9% SG contribution rate and the 12% SG contribution rate using a stationary bootstrap simulation.

Asset Allocation	Median RWR	Median RR
100% Cash	3.59	23%
Moderate	9.41	60%
DOA	10.78	68%
Balanced	12.32	78%
100% Stocks	18.71	119%
TDF	12.55	80%
DLC	15.26	97%

Table 5: Median RWR and RR results for each asset allocation under a 9% SG provision using a stationary bootstrap simulation.

Asset Allocation Strategy	Min	Median	Mean	P25	P75	Max	IQRR
100% Cash	2.12	3.59	4.14	2.99	4.73	20.42	0.48
Moderate	3.14	9.41	11.02	7.33	12.88	70.81	0.59
DOA	2.98	10.79	12.67	8.24	15.06	94.89	0.63
Balanced	2.81	12.32	14.60	9.19	17.50	126.52	0.67
100% Stocks	2.29	18.71	23.29	12.48	28.65	291.74	0.86
TDF	2.84	12.55	15.00	9.34	17.91	126.06	0.68
DLC	2.29	15.26	18.69	10.78	22.63	182.81	0.78

Table 6: Distribution statistics for each asset allocation strategy in RWR units using a stationary bootstrap simulation.

Asset Allocation	σ (RWR)	LPM_{FS}	LPM_{MS}	LPM_{SV}	Sortino Ratio	UPR
100% Cash	1.75	0.9300	2.9423	10.3964	-0.87	0.04
Moderate	5.60	0.1962	0.1795	0.2580	8.01	8.36
Default Option Average	6.77	0.1165	0.1090	0.1605	14.27	14.54
Balanced	8.32	0.0792	0.0779	0.1219	21.92	22.14
100% Stocks	16.94	0.0400	0.0493	0.0992	51.86	52.02
TDF	8.7294	0.0726	0.0691	0.1066	24.65	24.86
DLC	12.21	0.0338	0.0418	0.0865	39.92	40.06

Table 7: Path volatility measures for the accumulation paths under each of the seven asset allocations (TRF, TDF and DLC) using a stationary bootstrap simulation. Each LPM is a measure of downside risk relative to a RWR_{target} of 6.95. LPM_{FS} represents the probability of falling short of the retirement target, LPM_{MS} represents the expected shortfall below this target and LPM_{SV} represents the below target semi-variance. The Sortino ratio and the *UPR* evaluate the performance of each TRF relative to an RWR_{target} of 6.95.

Asset Allocation Strategy	VaR (RWR)	ETL (RWR)
9% contribution Rate		
100% Cash	2.51	2.40
Moderate	5.61	5.07
Default Option Average	6.02	5.35
Balanced	6.35	5.56
100% Stocks	7.29	6.00
Lifecycle	6.52	5.66
Dynamic Lifecycle	7.31	6.18
12% contribution Rate		
100% Cash	3.38	3.22
Moderate	7.46	6.71
Default Option Average	7.96	7.05
Balanced	8.43	7.29
100% Stocks	9.55	7.73
Lifecycle	8.57	7.43
Dynamic Lifecycle	9.63	7.98

Table 8: Tail related risk measures using a stationary bootstrap simulation.

Scenario	IRR	Geometric return	Average Return	Total Contributions	RWR	TW	IRR	σ
(1) 9%DLC	7.50%	8.45%	9.26%	$487,559	7.41	$2,007,839	7.50%	41.73%
(2) 12% Moderate	6.19%	6.70%	6.97%	$650,079	7.41	$2,006,480	6.19%	25.04%

Table 9: Total contributions, terminal RWR, terminal wealth, IRR and standard deviation of returns (annualized) for sample paths of the 9% SG DLC strategy and the 12% SG TRF moderate strategy.

Figures

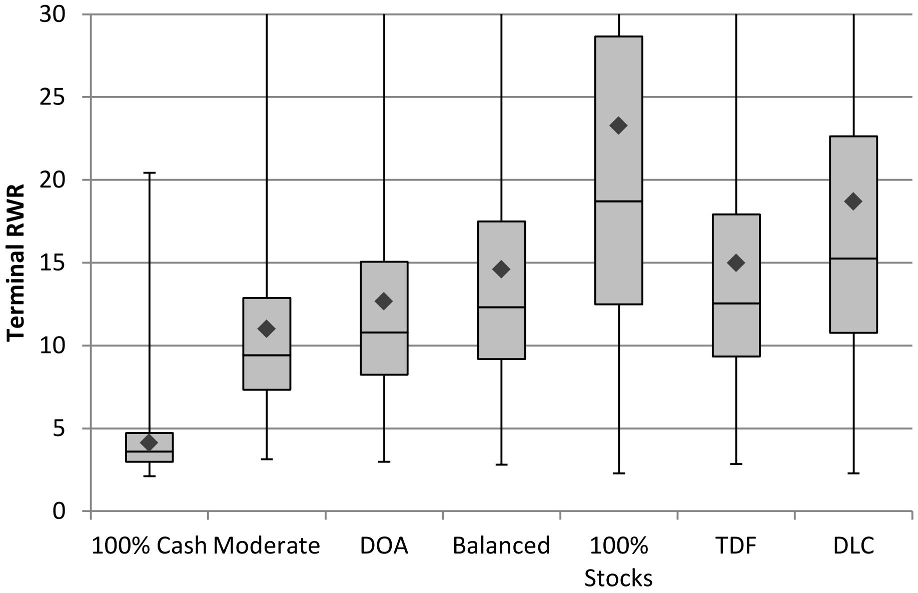

Figure 1: Comparative box-and-whisker plots for each of the seven asset allocations using a stationary bootstrap simulation. RWR scale set to a maximum of 30.

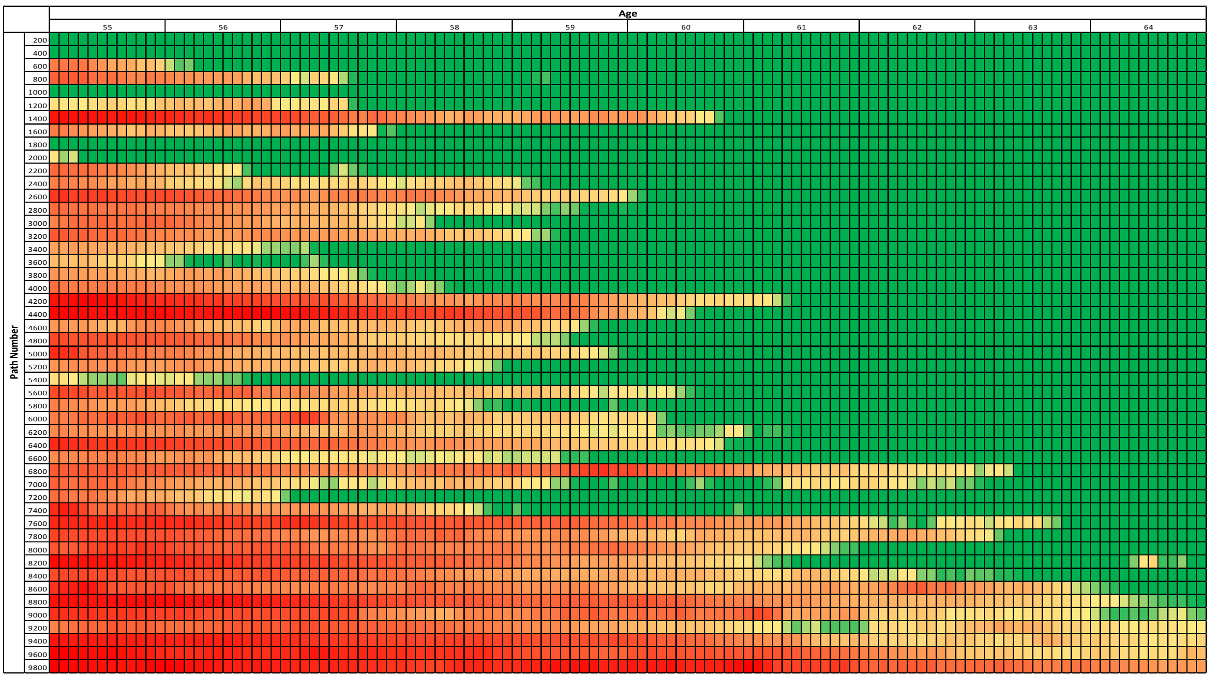

Figure 2: Balanced TRF heat map in the retirement risk zone using a stationary bootstrap simulation. RWR sequence for every 200th path, ordered best to worst, for the balanced TRF strategy in the last decade before retirement.

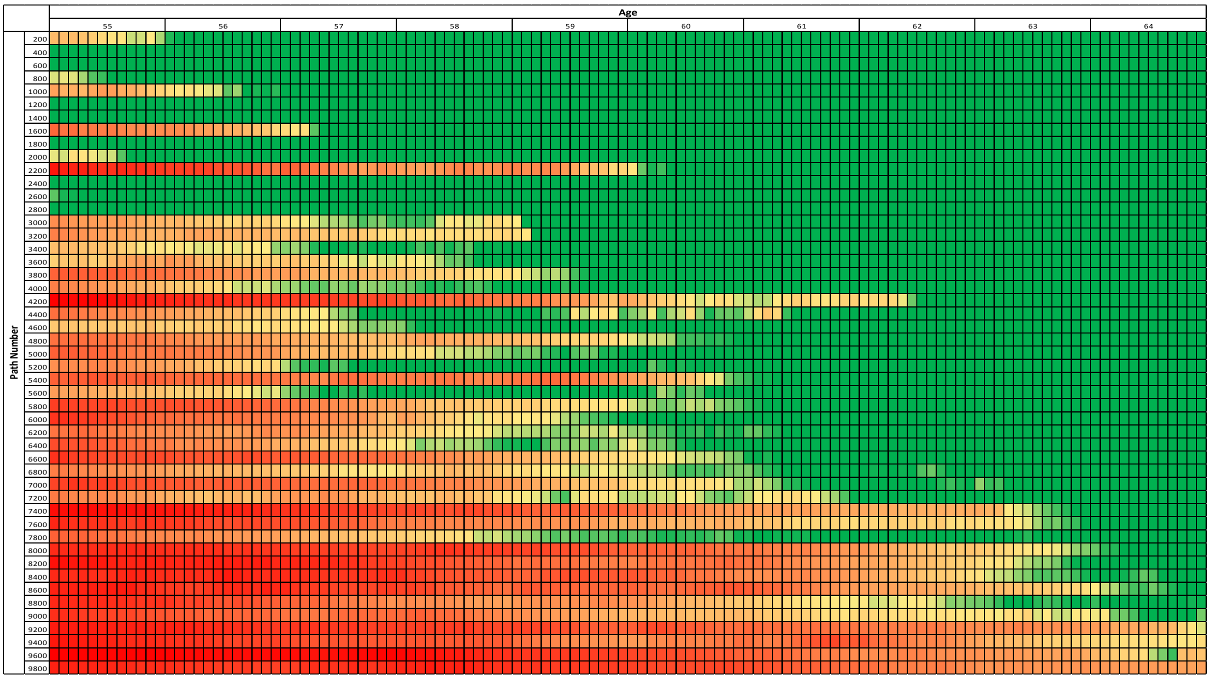

Figure 3: TDF heat map in the retirement risk zone using a stationary bootstrap simulation. RWR sequence for every 200th path, ordered best to worst, for the TDF strategy in the last decade before retirement.

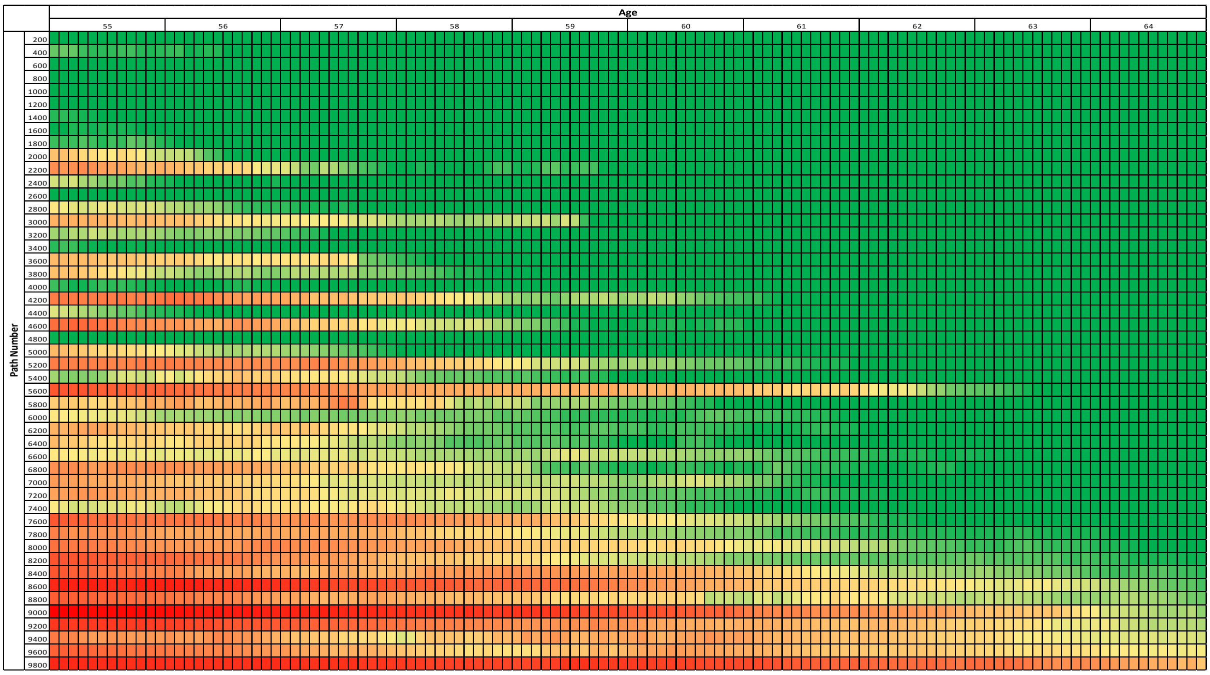

Figure 4: DLC heat map in the retirement risk zone using a stationary bootstrap simulation. RWR sequence for every 200th path, ordered best to worst, for the DLC strategy in the last decade before retirement.

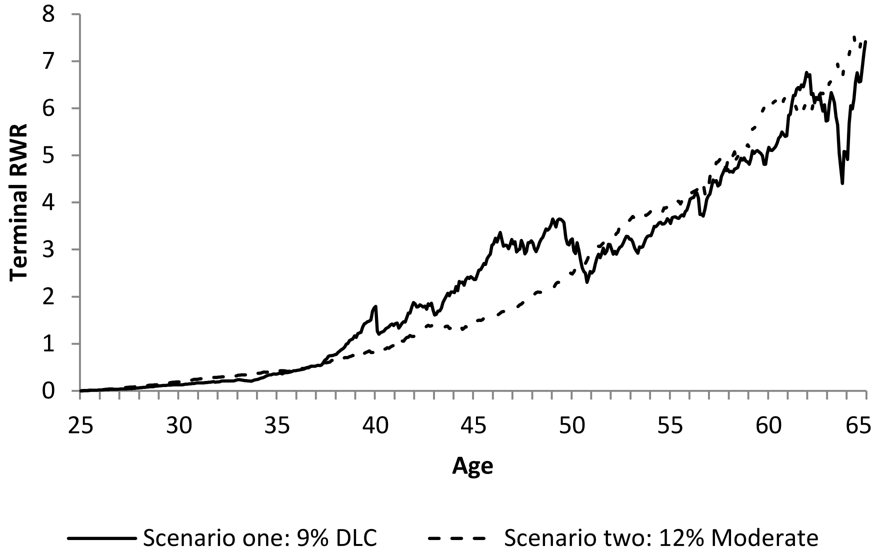

Figure 5: Accumulation paths for a 9% SG DLC strategy and 12% SG TRF moderate strategy.

Appendix

Asset Allocation Strategy	Min	P25	Median	Mean	P75	Max	IQRR	Std Dev
9 % Contribution Rate								
100% Cash	3.22	3.70	3.79	3.80	3.89	4.37	0.05	0.14
Moderate	3.47	7.96	9.78	10.36	12.13	31.78	0.43	3.38
DOA	3.34	8.78	11.13	11.92	14.18	47.78	0.49	4.41
Balanced	3.30	9.71	12.72	13.86	16.66	69.01	0.55	5.82
100% Stocks	2.77	12.79	18.47	21.95	27.03	166.75	0.77	13.64
TDF	3.21	9.88	13.02	14.19	17.05	72.57	0.55	6.09
DLC	2.85	11.57	16.24	19.00	23.21	143.25	0.72	10.94
12% Contribution Rate								
100% Cash	4.43	4.93	5.06	5.06	5.19	5.86	0.05	0.19
Moderate	3.98	10.59	13.02	13.77	16.15	52.78	0.43	4.49
DOA	4.60	11.77	14.92	15.98	18.87	75.19	0.48	6.00
Balanced	3.87	12.89	16.81	18.38	22.20	91.32	0.55	7.82
100% Stocks	3.45	17.02	24.69	29.59	36.26	325.87	0.78	19.10
TDF	4.29	13.06	17.26	18.80	22.65	88.89	0.56	8.07
DLC	2.98	15.55	21.84	25.08	30.62	191.45	0.69	13.93

Table A1: Extended summary statistics of Monte Carlo simulation of RWR distributions for seven asset allocation strategies.

Asset Allocation Strategy	Min	P25	Median	Mean	P75	Max	IQRR	Std Dev
9% Contribution Rate								
100% Cash	3.20	3.70	3.79	3.80	3.89	4.51	0.05	0.15
Moderate	3.37	7.93	9.80	10.35	12.16	39.58	0.43	3.43
DOA	3.36	8.78	11.12	11.90	14.13	55.26	0.48	4.44
Balanced	3.04	9.65	12.58	13.72	16.51	77.30	0.55	5.86
100% Stocks	2.31	12.69	18.48	21.94	27.06	222.33	0.78	14.21
TDF	2.91	9.79	12.82	14.09	16.96	81.09	0.56	6.19
DLC	2.31	10.92	15.35	17.67	21.50	127.42	0.69	9.94
12% Contribution Rate								
100% Cash	4.38	4.94	5.05	5.06	5.18	5.86	0.05	0.19
Moderate	4.52	10.67	13.09	13.88	16.28	52.74	0.43	4.56
DOA	4.41	11.83	14.87	15.95	18.98	69.53	0.48	5.90
Balanced	4.21	13.01	16.83	18.40	22.11	91.41	0.54	7.74
100% Stocks	3.35	17.16	24.72	29.43	36.38	232.79	0.78	18.58
TDF	4.55	13.23	17.15	18.88	22.64	88.85	0.55	8.13
DLC	3.35	14.80	20.44	23.66	28.80	143.03	0.68	13.02

Table A2: Extended summary statistics of Efron (1979) bootstrap simulation of RWR distributions for seven asset allocation strategies.

Asset Allocation Strategy	Min	P25	Median	Mean	P75	Max	IQRR	Std Dev
9% Contribution Rate								
100% Cash	2.12	2.99	3.59	4.14	4.73	20.42	0.48	1.75
Moderate	3.14	7.33	9.41	11.02	12.88	70.81	0.59	5.60
Default Option Average	2.98	8.24	10.79	12.67	15.06	94.89	0.63	6.77
Balanced	2.81	9.19	12.32	14.60	17.50	126.52	0.67	8.32
100% Stocks	2.29	12.48	18.71	23.29	28.65	291.74	0.86	16.94
TDF	2.84	9.34	12.55	15.00	17.91	126.06	0.68	8.73
DLC	2.29	10.78	15.26	18.69	22.63	182.81	0.78	12.21
12% Contribution Rate								
100% Cash	2.82	4.03	4.79	5.53	6.26	45.22	0.47	2.37
Moderate	4.20	9.81	12.49	14.65	17.05	136.09	0.58	7.68
DOA	3.90	10.97	14.37	16.80	19.67	146.65	0.61	9.15
Balanced	3.60	12.14	16.47	19.32	22.94	156.68	0.66	11.10
100% Stocks	2.82	16.42	24.77	30.56	37.57	333.13	0.85	21.97
TDF	3.74	12.38	16.78	19.84	23.63	171.56	0.67	11.65
DLC	2.28	14.18	20.43	24.66	29.84	252.16	0.77	16.14

Table A3: Extended summary statistics of stationary bootstrap simulation of RWR distributions for seven asset allocation strategies.