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Osei K. Wiafe, Anup K. Basu, John Chen

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Asset Allocation in Retirement: Does Glide path Matter?

Osei K. Wiafe[1]
Griffith Business School, Griffith University
Brisbane, Australia

Anup K. Basu
School of Economics and Finance, Queensland University of Technology
Brisbane, Australia

John Chen[2]*
School of Economics and Finance, Queensland University of Technology
Brisbane, Australia

Abstract

We compare the performance of the commonly nominated default retirement investment option, the lifecycle fund, to alternative investment strategies during retirees' decumulation phase. Under different shortfall risk measures, we find balanced portfolios with constant exposure to equities, equity dominated portfolios as well as 'reverse lifecycle' portfolios that increase exposures to equities over time to consistently outperform the conventional lifecycle portfolio. While an increasing equity glidepath improves the performance of an investment strategy, the starting asset allocations are equally important. Using a utility-of-terminal wealth approach which allows for loss aversion as discussed in prospect theory by Kahneman and Tversky (1979), we find the Growth portfolio to dominate the alternative strategies at low and moderate thresholds. With increasing wealth threshold levels, a strategy with all equity allocations becomes dominant. The lifecycle portfolio is dominated by the 'reverse lifecycle' portfolio at all threshold levels.

Keywords: Asset Allocation, Lifecycle, Prospect Theory, Glidepath, Shortfall Risk, Retirement

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[1] Corresponding author, Griffith Business School, Department of Accounting, Economics and Finance, Griffith University, 170 Kessels Road, Nathan QLD 4111, Australia, email: o.wiafe@griffith.edu.au
[2] Basu and Chen are Senior Lecturers in Finance at the School of Economics and Finance, Queensland University of Technology, Australia.
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With significant improvements in mortality in the last century, planning for old age has become a pivotal issue in many developed countries. Individuals are expected to take appropriate measures in their working lives when they have adequate human capital to build a good portfolio to support their retirement. It is equally important in retirement that retirees invest optimally to ensure that they do not outlive their available wealth. Whilst there is extensive academic research into building a well-diversified and sustainable investment portfolio during one's working life, the same cannot be said for the decumulation phase after the point of retirement. Increasing life expectancy is a strong incentive to adequately manage retirement wealth.

To sustain retirement income, retirees may purchase life annuities, which provide periodic income for life. Alternatively, they could invest their retirement wealth in a range of equities (risky assets), bonds and cash (non-risky assets) and make periodic withdrawals to meet their income needs. Self-annuitisation is preferred for the flexibility, liquidity and control it gives retirees over their wealth. Self-annuitisation strategies; however, provide no investment or longevity protection. What is the best investment strategy to help retirees meet their income needs as well as lower the chances of exhausting their long term savings? There is no definitive answer to this question and no consensus reached in previous literature. But whatever the strategy is, it must be a function of a retiree's age, health status, risk tolerance levels, as well as the total value of her assets and her desire to leave bequests among others. Diversification of underlying investments into different asset classes is essential and reduces an investor's overall risk.

While there is no consensus on what the best investment strategy is, current debate questions the benefits of the popular target-date or lifecycle funds in the accumulation phase. Blanchett [2007] compares fixed asset allocations to a wide range of investment paths that reduce the allocation to equity during retirement. He finds that fixed asset allocations provide superior results compared to asset allocations which tend to reduce equity investments in retirement. Arnott, Sherrerd, and Wu [2013] argue that a reverse approach to the target-date fund glidepath with increasing equities delivers greater terminal wealth levels for investors. They yield higher wealth levels than the traditional lifecycle approach even at the left tail of the wealth distribution. Estrada [2014] comprehensively studies the lifecycle investor glidepath in 19 countries, finding that contrarian strategies provide higher upside potential, more limited downside potential, although with higher uncertainty. Surz [2013] however, asserts that what matters most in retirement planning is not the direction of allocations or glidepaths but saving enough before retirement. He stresses that no glidepath is able to compensate for inadequate savings.

Needless to say, the decumulation phase has not received much attention in this respect. A significant contribution in this space is by Pfau and Kitces [2013]. They find that a rising equity glidepath from conservation starting points achieves superior results compared to the fixed or decreasing glidepaths. Our article contributes to this important debate on investments and asset allocation in the retirement distribution phase in several dimensions. Previous propositions of a reverse target-date fund style has been mainly limited to the benefits of wealth outcomes in the accumulation phase, this article proposes a similar approach to investment in the post-retirement phase. The impact of income drawdowns rather than contributions in retirement presents a different outlook for analysis.

For the first time, not only can we measure the terminal wealth but we are able to investigate which investment strategies are able to sustain income levels in retirement via an annuity equivalent approach. We examine how much guaranteed income one is able to purchase with her terminal wealth resulting from the alternative strategies after a period in retirement. This further enables a comparison of strategies on a broader basis such as portfolio ruin, ruin magnitude and income shortfall in retirement. Secondly, unlike the straight-line linear increase approach considered in previous studies, we include different hybrids of the lifecycle and static investment approaches. Specifically, we consider two partial lifecycle models which are a combination of a static allocation and the lifecycle and reverse lifecycle approaches. This enables comparison of strategies based on increases or decreases in the equity glidepath from defined static starting points. Finally, we explain our results from the perspective of investment strategy preferences using retiree's expected utilities based on prospect theory.

Our findings reveal that the dependence on the target-date fund approach creates an illusion of security in retirement, mainly because of its low standard deviation, and should be reconsidered. Firstly, in terms of terminal wealth outcomes, contrarian strategies outperform conservative and traditional strategies with decreasing equity glidepath, even at the lowest percentiles. Mean and median wealth levels are higher for contrarian strategies compared to lifecycle and more conservative approaches. This enhances the chances of meeting income replacement levels akin to pre-retirement income. Secondly, lifecycle strategies limit the upside potential of retirement wealth, creating difficulty in meeting capital preservation needs such as for aged-care, or future annuity purchasing. Contrarian strategies with higher standard deviations have high volatility on the upside, creating good upside potential resulting in extremely high outcomes in many cases. Thirdly, utility-of-terminal wealth analysis show preference for aggressive static asset allocation models, balanced strategies and strategies with periodic increases in equities, at different wealth thresholds. We find the lifecycle style strategy to underperform more aggressive portfolio strategies. Finally, the results show that increasing the equity glidepaths does not necessarily make a better strategy; investment performance is significantly impacted by the starting asset allocations of the investment.

The remainder of this paper is structured as follows. The next section introduces the background and assumptions of the paper. We also discuss retirement wealth, retirement income, mortality and asset allocation. The section that follows explains the methodology, simulation set-up, prospect theory utility and analysis. The subsequent section contains the results of the article and the conclusion makes up the final section.

Background and Assumptions

Retirement Wealth

Starting wealth at retirement age is a result of accumulated savings and growth on savings achieved through periodic contributions throughout the accumulation period. We do not analyse the lead up to retirement age but assume the investor has a nest egg at retirement and this forms the basis of our asset allocation. Investors do not purchase annuities immediately at retirement but make systematic periodic withdrawals from their retirement wealth to meet consumption needs. They invest the remainder of their wealth according to a strategy of their choice and earn returns on their investments. This investment has no longevity or investment guarantees and may deplete whilst the investor is still alive.

We begin our analysis with an initial retirement starting balance of $1,000. While the choice of starting balance is important and may potentially influence the results in terms of portfolio sustainability and shortfall, our starting balance indicates that a level of initial wealth is not the focus of this article.[3]

Retirement Income

We discuss two main retirement conversion approaches, the Systematic Withdrawal Plan (SWP) and the guaranteed income plan as expounded by Schaus [2010]. The first is a drawdown approach that consists of income from both the principal and interest earned on it. The second plan is for investors with low risk tolerance or those who anticipate high longevity; they convert all or part of their assets into an immediate or deferred income producing annuity. We consider these two as the majority of retirees need to actively manage their retirement wealth and make systematic withdrawals or purchase guarantees to meet their income needs in retirement.

We acknowledge the diverse and varied conclusions on the sustainability of the 4 per cent 'golden rule' as proposed by Bengen [2004]. Whilst some studies firmly support this withdrawal rate (see Pye [2000]; Guyton [2004]; Guyton and Klinger [2006]), recent literature questions the sustainability of the 4 per cent 'safe withdrawal rate' and its ability to sustain retirement portfolios. Spitzer, Strieter, and Singh [2007] and Spitzer [2008] suggest that the 4 per cent rule may be an oversimplification while studies by Sharpe, Scott, and Watson [2007] believe the rule is inefficient. Other studies which oppose the 4% percent rule include Harris [2009], Pfau [2011], and Drew and Walk [2014]. Based on a comprehensive analysis across 19 countries, Drew and Walk [2014] argue that the 4 per cent rule does present us with an opportunity to form a baseline which can dramatically improve the expectations of what is possible in retirement but is not a silver bullet approach to retirement withdrawal decisions.

Considering the importance of an appropriate drawdown rate, we use a 4 per cent rate as our baseline, investigating the sustainability of other withdrawal rates ranging from 3 per cent to 7 per cent of initial wealth. After 20 years of investing, the terminal wealth resulting from alternative strategies is converted into a guaranteed income, specifically a whole life annuity. With increasing life expectation, guarantee income products are increasingly becoming

[3] Our choice of starting balance is influenced by previous literature in using a scalable figure. See Arnott [2012] and Estrada [2014].

attractive and we consider how much income the different investment strategies generate from their terminal wealth levels. For the remainder of the analysis, the individual considered here makes monthly drawdowns over a period of 30-years.

Mortality

There has been a significant increase in human longevity in the last century. Findings by Oeppen and Vaupel [2002] reveal that female life expectancy in the last century has been increasing steadily by almost three months every year. The increase in life expectation also increases longevity risk associated with retirement planning. Longevity risk refers to the uncertainty of the age of death and the likelihood of a retiree outliving her wealth. Of relevance to this article are the mortality characteristics of individuals between retirement age 65, and age 100. According to findings by the U.S. National Center for Health Statistics as reported by Kochanek, Murphy, Xu, and Arias [2014], a couple both aged 65 have a life expectation of 19.3 years. Independently, males have an average life expectation of 17.9 years while the female counterparts have up to 20.5 years life expectation in retirement. The median life expectation is around 86 years whilst a tenth of the population at 65 years will grow to age 96. This requires a retiree who wants to be 90 percent certain that her retirement savings last as long as she lives to plan for her consumption and investment for up to 31 years. With the 30-year investment horizon, we adequately cater for the 10th percentile of retirees who will live beyond age 95.

Asset Allocation

Bengen (1997) advises that if the future market returns follow the trends of behaviour in the past, then a retirement portfolio should hold a 50 to75 per cent allocation to equities. Milevsky [2001] and Ameriks, Veres, and Warshawsky [2001] demonstrate through simulation, the need for holding a substantial equity allocation in a retirement portfolio. Cooley, Hubbard, and Walz [2001] propose that at least 50 percent of a retirement portfolio should be invested in equities and their findings show increased sustainability of the fund as it tilts more towards equities. They explain that the presence of bonds is mainly to restrain portfolio volatility and provide liquidity to cover an investor's living expenses. Hubbard [2006] considers different withdrawal rates given various asset allocations and fixed withdrawal periods, emphasizing the benefits of holding an equity dominated portfolio.

The lifecycle strategy holds a high allocation to equities at the onset but moves towards less volatile assets, such as bonds and cash with increasing age. This is the default investment option in many employer-sponsored and individual retirement plans (see Charlson and Lutton [2012]). In Australia, lifecycle funds are increasing rapidly, expected to catch up or surpass the U.S. in the next decade (QSuper [2014]). The lifecycle approach is implemented with the aim of avoiding insufficient diversification as well as to avoid investment choices that may be age-inappropriate. While it undoubtedly achieves these aims, the relevance of having investments following a predetermined glidepath solely dependent on age appears simplistic. Important factors such as account balance, gender, marital status, retirement income expectations and life expectancy improvements influence the asset allocation decision.

We analyse eight different asset allocation strategies which we fully discuss in the next section. There are four different static Strategic Asset Allocation (SAA) strategies ranging from a Conservative strategy, with total investment in bills and bonds to an Aggressive approach, where the strategy completely indulges in equities. There is the target date funds approach which we refer to as the Lifecycle strategy where the allocation to equities is reduced over time and a Reverse Lifecycle approach with increasing allocation to equities over time. Finally, there are two partial lifecycle strategies which are hybrids of the static and the lifecycle approaches.

Methodology

Simulation set-up and Strategies

We use historical monthly returns data on U.S. equity, bonds and bills between January 31, 1928 and January 31, 2014, spanning a period of 85 years sourced from the Global Finance Database (GFD). We may subsequently refer to equities as growth assets and bonds and bills as conservative assets through the remainder of this article. From the data, we obtain 2 independent non-overlapping 30-year holding period observations. The initial cohort of retirees begins their investment horizon in 1928 until 1958, when they attain age 95. There are 56 overlapping 30-year cohorts, with the final cohort beginning in 1984 and ending in 2014. While the use of overlapping returns have been used in previous studies (see Hubbard [2006]; Cooley et al. [2001]; Bengen [2001], [2004]), we believe this is insufficient to draw a reliable conclusion.

To cater for the insufficient data, we use block bootstrap resampling to generate 30-year return time series. This involves sampling blocks of consecutive values of the original returns time series, say $X_{i+1},...,X_{i+b}$ where $0 \leq b \leq N-b$ is chosen in some random way; and placed one after the other in an attempt to reproduce the 30-year time series. Where b denotes block length and *N*, the length of the time series. Specifically, we use a 'moving block' bootstrap technique which allows for block overlap making the *ij's* independent and uniformly distributed on the values *1, ..., N − b*. Since the return matrices hold rows of the different asset class returns, we are able to preserve the cross-correlation between the asset returns and well as correlation within the various asset returns within each block. By using historical rolling returns, we are able to ascertain through historical evidence the success or failures of the various retirement investment plans. Kunsch [1989] explains in detail how and why such a block bootstrap works in his seminal paper. More recent use of this methodology is detailed in Basu, Chen, and Clements [2014].

We employ a block bootstrap resampling of 5-year lengths based on the return vectors for the three asset classes in the dataset. We randomly resample the return vectors with replacement from the empirical return distribution to generate 30-year asset class return vectors. We repeat the procedure to construct 10,000 replica return time series. We allow for monthly income drawdowns from our wealth levels and this serves as retirement income for the plan participant. The level of income is chosen according to a percentage of wealth approach which is adjusted annually for inflation. Our simulations are based on retirees choosing one of eight asset allocation strategies at retirement age and holding that strategy for the remainder of their lives.

The retirement investment plans analysed in this article include four static Strategic Asset Allocation (SAA) plans, a target-date approach, a contrarian strategy and two hybrid strategies. The SAA strategies involve setting target allocations for various asset classes in a portfolio. This is periodically re-balanced back to the original allocations when they deviate from the initial settings due to differing returns from various assets and periodic withdrawals made from the portfolio. This is a typical "buy and hold" strategy and the choice of target allocations depend on the retiree's risk tolerance level, investment objectives as well as investment time horizon. The SAA model is based on modern portfolio theory's rationality of diversifying among various assets to increase overall portfolio returns.

The different strategies include:

- *Conservative*: The conservative plan allocates the retiree's entire wealth to conservative assets, holding an equal allocation to bonds and bills. This plan is rebalanced after returns and income drawdowns to assume the set asset allocations for the entire investment horizon.
- *Balanced*: The balanced plan allocates the retiree's wealth equally between growth and conservative assets; holding a static 50% in equities and the remaining 50% in bonds and bills. This is rebalanced monthly throughout the 30-year horizon.
- *Growth*: The growth plan allocates 70% of the retiree's wealth to equities and the remaining is shared between bonds and bills. This set allocation is held by the retiree throughout the investment horizon regardless of the nature of returns.
- *Aggressive*: The aggressive plan allocates all of the retiree's wealth to equities at retirement. The retiree thus maintains a 100% allocation to growth assets throughout her horizon with periodic rebalancing to the target allocation.
- *Lifecycle Strategy (LC)*: This strategy begins with an equal allocation between growth and conservative assets, with the growth assets gradually reduced to 0% at the end of the investment horizon. As the allocation to growth assets is reduced, the allocation to conservative assets is increased, with the retiree switching to a full investment in conservative assets by the end of the investment period.
- *Reverse Lifecycle (RLC)*: This approach works in opposite to the Lifecycle strategy. The retiree begins investment with a balanced allocation to conservative and growth assets at retirement. She gradually increases the allocation in growth assets until the investment is fully invested in growth assets at the final year in retirement. This is against the conventional wisdom of increasing investment in conservative assets with increasing age.
- *Partial Lifecycle (PLC)*: This strategy is a variant of the Lifecycle strategy; the retiree commencing with a 100% equity investment and reduces this to an equal allocation to growth assets and conservative assets in the final investment period. A constant fraction of the portfolio, which is 50% in this case, is held in growth assets. The

remaining 50% is invested fully in growth assets at the onset and reduces to a full investment in conservative assets at the end of the time horizon. Thus, this strategy has a lifecycle and static allocation component.

- *Partial Reverse Lifecycle (PRLC)*: This is another variant of the Lifecycle strategy, with the retiree begins investment with a 100% allocation to bonds/bills and reduces to an equal allocation to growth assets and conservative assets in the final investment period. A constant fraction, 50% of the conservative asset is held at the beginning of the investment horizon. The remaining 50% is invested fully in conservative assets at the onset and reduces to a full investment in growth assets at the end of the horizon. Thus, this strategy has a reverse lifecycle and static allocation component.

Prospect Theory

An ultimate concern is that wealth outcomes from investment strategies are able to generate income to meet needs in retirement. To meet certain income replacement ratios, strategies will need to meet different wealth thresholds. To put this in perspective, these thresholds are necessary to provide income which is equal to or exceeding a sustainable income benchmark. We use a utility measure that accounts for a threshold level of wealth, comparing the alternative strategies based on gains and losses. To do this, we incorporate the concept of loss aversion, which is the tendency for individuals to be more sensitive to a reduction in their wellbeing than to increases. We refer to the utility function approach as motivated by Kahneman and Tversky [1979] prospect theory. The prospect theory utility has a kink at the origin, with the slope of the loss function being steeper than the slope of the gain function. We compare alternative investment strategies for various wealth thresholds.

This measure is in line with work by Poterba, Rauh, Venti, and Wise [2007] and is represented as:

$$U(W) = \frac{(|W-K|)^{1-\gamma}}{1-\gamma} \quad \text{if } W > K \tag{1}$$

$$U(W) = -h\frac{(|W-K|)^{1-\gamma}}{1-\gamma} \quad \text{if } W < K \tag{2}$$

Where W is wealth, γ is the relative risk aversion parameter, *h* is the loss aversion parameter and *K* is the threshold wealth for sustenance.

The utility function, consistent with prospect theory, has agents framing their choices in terms of gains and losses or deviations relative to a threshold level rather than levels of wealth. The utility's value function is generally concave on the region of gains and convex in the region of losses. If the retirement wealth is above the referenced wealth level, the constant relative risk aversion (CRRA) utility applies. If the retirement wealth falls below the referenced wealth level, the CRRA utility is adjusted to incorporate the loss aversion parameter *h*, allowing for steeper convexity as individuals are more sensitive to losses and hence heavily punish such outcomes. We calculate the utility levels for 10,000 simulations per strategy, $U(W_i)$, and derive the probability weighted expected utility as the expected utility for the strategy:

$$E[U(W)] = \sum_{i=1}^{N}(U(W_i)) \qquad (3)$$

Where N is the total number of simulated return paths.

Results & Discussion

We compare alternative strategies based on the chances of portfolio ruin. This is the probability that the strategy ends with a negative balance after the 30-year investment horizon. The ruin probability is calculated on the assumption that the strategy provides periodic drawdowns to the plan participant over the investment period. When portfolio ruin occurs, the strategy ceases as we do not allow for negative gearing. We compare the investment strategies based on their ruin probabilities to determine which of the plans have a higher chance of being sustainable in the long term. Adequacy and sustainability of retirement plans are foremost in retirement planning and the achievement of these for reasonable drawdown rates are important for any strategy. We analyse different withdrawal rates ranging between 3% and 7% of initial wealth which we adjust annually for inflation in subsequent withdrawals. We use the widely accepted 4% of initial wealth as the baseline withdrawal case for comparison purposes. We present the ruin probabilities of the various investment strategies in Exhibit 1.

<Exhibit 1 Here>

At low withdrawal rates of 3%, the Conservative strategy has a 1% chance of ruin while the remaining strategies are sustainable throughout the investment period. There is portfolio ruin for all strategies at 4% of initial withdrawal, with the Conservative strategy increasing to 35% chance of ruin and the Partial RLC strategy to 10%. The LC strategy has just over a percent ruin chance while the remaining strategies have up to 99^{th} percentile not facing ruin. For higher initial drawdown rates between 5% and 7%, we find very pronounced differences in the ruin patterns for the different investment strategies. These differences are mainly seen for varying equity levels of the various strategies. Whilst the instances of ruin increases for all strategies, the rate of increase is higher for the Conservative, Partial RLC and LC strategies compared to the remaining strategies. The ruin probability decreases as we increase our allocation to equities, from Balanced, through Growth to Aggressive strategies. At 7% of initial withdrawal, the Conservative and Partial RLC have ruin probabilities exceeding 90%. While the LC strategy fails in 4 of every 5 simulations, the Reverse LC faces ruin in half of the simulations. The Aggressive strategy which has the lowest ruin chances of 22% while the Partial LC fails in 28% of the simulations at this drawdown rate.

At low drawdown levels, all the strategies appear fairly sustainable and barely face portfolio ruin. Whilst the instances of ruin are generally low for the equity dominated portfolios with increasing initial withdrawal rates, we observe significant ruin levels for the conservative strategies. At high rates of withdrawal, we observe an increasing in the ruin probabilities with low equity levels. There is substantially high ruin chances observed for the Conservative and Partial RLC strategies; we find this statistic to decrease through a Balanced, Growth to the Aggressive strategies. This means higher initial withdrawal rates are better supported by a higher static allocation to equities. The Reverse LC has lower ruin chances compared to the LC. This shows that for different equity glidepaths for two strategies with same starting allocations, portfolio sustainability is improved by increasing allocation to risky assets rather than decreasing risky asset allocation over time as is the traditional practice. The Partial RLC also runs into ruin on more occasions than the Partial LC. This is evidence of the importance of portfolio starting allocations. A decreasing equity glidepath from aggressive starting points is more sustainable than an increasing equity glidepath from purely conservative starting points.

Should portfolio ruin occur, we compare the extent of portfolio shortfall for the different strategies. The extent of ruin in this case is quantified by the length of time, in years, the strategy is unable to meet the required periodic drawdown. We define shortfall years as the final year in the investment horizon less the ruin year. Justification for this approach is expounded in the works by Butt and Deng [2012]. This method answers the question of how large the potential shortfall may be or the magnitude of the portfolio ruin. For each of the investment strategies, we measure the mean shortfall years, the maximum shortfall years and the number of times ruin years exceeding the mean shortfall. The mean shortfall years, the average number of years a strategy is in portfolio ruin is our measure of shortfall severity. We show the analysis of shortfall for the different strategies for the different withdrawal rates in Exhibit 2.

<Exhibit 2 Here>

At a low initial rate of withdrawal of 3%, the only strategies that face ruin are the strategies with all conservative and all equity allocation starting points. The Aggressive strategy has the highest mean and maximum shortfall years while the Conservative strategy has a higher number of simulations experiencing ruin although the maximum shortfall is lower. At 4% initial withdrawal, the equity dominated strategies have higher mean and maximum shortfall levels. The number of simulations which exceed the mean shortfall years however remains lower compared to the significant numbers which exceed the means for the more conservative strategies. While the extent of shortfall may be significant, it has a low chance of occurring as seen earlier in Exhibit 1.

At higher rates of withdrawal between 5% and 7%, the mean shortfall years for the conservative strategies increase rapidly, exceeding the mean shortfall levels of the more aggressive portfolios. The mean shortfall years for the Conservative strategy and the Partial RLC increase from 7 years and 6 years to 13 years and 12 years respectively. The Aggressive and Partial LC over the same withdrawal rates increase from 7 years and 6 years respectively to 9 years. Of significance is the sharp increase in the numbers exceeding the mean shortfall for the conservative strategies over the more aggressive strategies. At the 7% initial withdrawal rate, the Conservative and Partial RLC strategies, have up to 6,165 and 5,800 simulations exceeding the mean shortfall. The Aggressive and Partial LC on the other hand, with lower mean shortfalls, have just over 1,000 simulations facing shortfall exceeding the mean level of 9 years. Another significant finding is that for retirees who choose the LC strategy, there are more outcomes exceeding the mean shortfall years than retirees with the Reverse LC strategy even though the mean shortfall for the latter is lower.

In summary, the equity dominated portfolios have higher mean shortfall years compared to the more conservative strategies at low rates of withdrawal. This means when portfolio ruin occurs, it is more pronounced for the aggressive investor than the conservative investor. The reverse is realised at increasing initial withdrawal rates, with mean shortfall years of the conservative strategies exceeding that of the more aggressive strategies. The maximum shortfall years however, are higher for the equity dominated portfolios than the balanced and conservative portfolios at all withdrawal rates. While a more aggressive strategy may experience potentially severe shortfall, the probability of facing these high levels of shortfall is extremely low as the mean shortfall levels are significantly lower than the maximum shortfall levels. The numbers of simulations showing shortfall levels exceeding the low mean years are also lower compared to the number of retirees who experience shortfalls under the more conservative strategies which have higher mean shortfall years.

Income Shortfall

Campbell and Viceira [2002] suggest that long term investors consume out of wealth and derive their utility from consumption rather than from wealth. Arnott et al. [2013] further echoes that for retirement purposes as it makes sense to gauge the success of a portfolio in terms of annuitized income rather than notional portfolio gains or losses. We consider a shortfall measure which is based on a retiree meeting a certain level of consumption. We compute income levels that the retiree is able to generate from her level of wealth after 20 years in retirement. We analyse how these income levels compare to a level annuity purchased at retirement date.

We compute fixed income amounts that can be generated from the terminal wealth resulting from the different strategies. We compare this to an annuity income available from fully annuitizing with a Single Premium Immediate Annuity (SPIA) at retirement age 65. This annuity pays a fixed amount of monthly income for life, hereafter referred to as the benchmark life annuity. The SPIA is calculated with rates made available from American International Group (AIG) Insurance Company and issued by American General Life Insurance Company (AGL)[4]. The rates used in this article are current as at July 6, 2015 and provides annuity income estimates based on individual’s age, gender and invested premium. The income from said annuity purchased at retirement age 65, with a premium of $100,000 is $383 per month, which translates into $4,596 per annum; 4.6% of starting wealth. This amount is indexed to inflation; hence we compute the dollar value of annual income after 20 years at 2% inflation.

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We estimate the income shortfall as the difference between the income generated from a strategy's terminal wealth and the expected income from a life annuity purchased at retirement age 65. The Shortfall Probability is calculated as:

$$SP(C_t) = P(C_t < z) \tag{4}$$

This is the probability that the guaranteed periodic income from terminal wealth of alternative strategies, C_t, is less than the benchmark z, in this case, the life annuity. Strategies that run into ruin after 20 years provide no income. Since the annuity used in this comparison is purchased at retirement age, we adjust for inflation and compared the annuity to income levels that are obtained from the alternative strategies at age 85.

<Exhibit 3 Here>

From Exhibit 3, we find large income shortfall probabilities ranging between 29%-95% for our range of withdrawals for the Conservative strategy. The Partial Reverse LC is the next strategy with the highest levels of income shortfall ranging between 9% for a 3% initial wealth withdrawal rate to 93% for a 7% withdrawal rate. The Reverse LC exhibits lower shortfall probabilities at all levels compared to the LC strategy. The Balance strategy does a good job, with shortfall probabilities ranging between 0% and 58% for the range of withdrawal rates analysed. The Growth strategy performs better than the Balanced strategy, while the Aggressive strategy has the lowest income shortfall probabilities among the eight strategies. The Partial LC which begins investment with a full allocation to equities is the second best performer in terms of meeting the income benchmark.

At the baseline withdrawal rate of 4%, we find the Conservative strategy to have the highest shortfall probability among the alternative investment strategies, falling below the annuity income threshold in more than half of the simulations. The Partial RLC falls below the benchmark in 39% of our simulations. These two represent the strategies with the highest conservative asset allocations. The Partial LC fails in only 3% of the simulations. The LC has up to 3 times the frequency of income shortfalls compared to the Reverse LC. The Balanced and Growth and Aggressive strategies also fall short of the benchmark income level by 3%, 2% and 2% respectively, the lowest shortfall probability observed.

Overall, we find the instances of income shortfall to be highest for the conservative strategies. Again, increasing equity allocation improves the chances of meeting a defined income level. The Balanced, Growth and Aggressive strategies are in increasing order of improving income outcomes. Reverse LC portfolios perform better at low withdrawal levels than the more aggressive portfolio which begin with an all equity allocation although the latter strategy performs better at high withdrawal rates. The Reverse LC strategy significantly and consistently outperforms the LC strategy whilst the Partial LC also consistently performs better than the Partial RLC, the more conservative variant.

Severity of Income Shortfall

We define the severity of shortfall as the size of benefit shortfall over the investment horizon. Should benefit shortfall occur, we analyse the severity of the shortfall and how it disperses on average throughout the investment period for the different strategies. The size of the benefit shortfall is calculated with reference to the income level provided by our benchmark annuity income. To calculate the size and extent of this income shortfall, we consider both the probability of shortfall and the average size of shortfall for each of the strategies considered. This is similar to the metric used in Dus, Maurer, and Mitchell [2005] which they refer to as the Shortfall Expectation (S.E.).

$$SE(B_t) = E(max(z - B_t, 0)) \tag{5}$$

Where z refers to the benchmark annuity income level and B_t refers to the benefit income level derived from the terminal wealth from the strategies. The Shortfall Expectation is therefore the sum of losses weighted by their probabilities. We compare the various strategies based on their Shortfall Expectations in Exhibit 4.

<Exhibit 4 Here>

We compare the income provided by the terminal wealth resulting from the different investment strategies to the annuity and evaluate how much these incomes fall short of the benchmark. There is no income shortfall observed for up to 4,000 of our 10,000 simulations, after which we find the Conservative strategy to experience benefit shortfall. The shortfall level rises gradually with the next 4,000 simulations facing benefit shortfalls of up to 50% of the benchmark annuity income. The shortfall level steadily increases, reaching 100% for about 2% of the cohort. This is the highest level of benefit shortfall experienced among the alternative investment strategies and it is essentially the proportion of simulations that run into ruin. The Balanced strategy on the other hand has up to the 98th percentile of the simulations generating income levels that are equal to or greater than the benchmark income. The remaining simulations which are exposed to shortfall show a steep rise in the shortfall levels, with the maximum level of shortfall below 80% of the annuity level.

The Partial RLC has 6,000 simulations not experiencing benefit shortfall. Of the remaining simulations, the level of shortfall increases steadily for the next 4000 simulations up to about 84% of the annuity level. The Partial RLC, unlike the Conservative strategy has no retirees experiencing total shortfall. The Partial LC plan and the Aggressive strategies have incomes equal or exceeding the benchmark in over 98% of our simulations. The remaining face short-fall levels rising sharply up to 100% of the annuity benchmark for about 10 of the 10,000 cohort. Comparing the LC to the Reverse LC, the former has a tenth of the simulations facing benefit shortfalls while the latter has up to the 97th percentile earning income equal or greater than the annuity benchmark. The rate of increase in shortfall levels is similar for both strategies but the Reverse LC is slightly steeper than the LC. Neither strategy experiences total income shortfall. The Growth and Aggressive strategies have very little variation in terms of shortfall to the benchmark. Shortfall occurs in up to 2% of the simulations in both strategies. The extent of shortfall rises steeply to 100% among the final 200 simulations that experience total shortfall in both strategies, with the Growth strategy having a steeper rise in shortfall than the Aggressive strategy.

Measuring the severity of shortfall based on how much income from the various strategies fall short of the benchmark annuity income, there is clear evidence of outperformance of the benchmark by equity dominating portfolios. The Aggressive, Growth, Partial LC, the Reverse LC as well as the Balanced strategies have up to 90% of terminal wealth levels providing income that is equal or higher than the benchmark level. The steep shortfall curve shows that although benefit shortfall occurs, a lower number of simulations are affected, reducing the probability of extreme shortfall. The defensive strategies provide less protection in meeting set income levels in retirement. Shortfall is more prevalent for these strategies, with the concave shortfall curve showing that many simulations experience increasing shortfall levels although total shortfall level is experienced only by a few simulations. The Balanced and LC strategies do not experience total shortfall, similarly, the Partial RLC which increases equity level from a conservative starting point does not experience total shortfall.

Terminal Wealth Analysis

We compare eight post-retirement strategies starting at retirement age 65 and maintained for an investment horizon of 30 years. We allow for monthly drawdowns from the strategies based on different initial withdrawal rates which are annually adjusted for inflation. A summary the statistics of the ending terminal wealth levels in Exhibit 5.

<Exhibit 5 Here>

Exhibit 5 shows the summary statistics of the terminal wealth of the eight investment strategies. The three highest average terminal wealth values are realised for the Aggressive, the Partial LC and Growth strategies respectively and this is accompanied by the highest standard deviations. The Reverse LC strategy generates a higher average ending wealth level than the remaining strategies. In particular, the Reverse LC ends with an average wealth level which is 3 times the size of the average ending balance for the LC strategy. These two strategies both have a balanced starting point with an equal allocation to risky and conservative assets. By increasing equity levels in the former, it performs up to 3 times better on average, with respect to the ending balance. Compared to the Balanced strategy, increasing equity levels from 50% to 100% increased the average ending balance by 20%, while reducing equity into a full conservative portfolio reduces the average balance by 45%. Holding a static allocation to only conservative assets, bonds and bills, yield the lowest ending balance among the strategies. Between the lifecycle variants, the Partial LC which begins with a full allocation to equity and reduces to form a balanced portfolio accumulates an average ending balance 6 times bigger than the Partial RLC which begins with a full allocation to conservative assets.

We find the median terminal wealth levels for the alternative strategies to be lower than their average terminal wealth levels. This is especially significant for the strategies with low equity allocations. The average terminal wealth for the Conservative strategy is twice the median while the Partial RLC average is 50% higher than its median. The mean of the Balanced, Growth and Reverse LC strategies are approximately 25% higher than their medians. A higher average compared to median signifies positive skewness in the distribution of terminal wealth, with less than half the cohort attaining the average terminal wealth. Considering the size of the average terminal wealth, a less than 50% chance of obtaining the average wealth is alarming for the strategies resulting in low average terminal wealth.

The Conservative strategy results in a negative balance through the 10th percentile. The Partial RLC strategy is only positive after the 10th percentile of terminal wealth, whilst the LC only ends in negative balance at the 1st percentile. The Growth, Reverse LC and Balanced strategies respectively are the best performers at the 1st percentile, with the Aggressive strategy having a higher balance than the Partial LC. At the 5th percentile, the Aggressive strategy accumulates the highest wealth balance; with the Growth and Partial LC having significantly high balances. The 75th percentile reflects the trend observed for the average terminal wealth, rewarding increasing equity allocation with increasing terminal wealth outcomes.

The varying terminal wealth levels associated with the Aggressive and Growth strategies, as well as the Partial LC are a depiction of the influence of equities at different levels in the investment portfolios. The impact of equities is significant in the portfolio dynamics as we find extreme differences in the equity and conservative asset dominated portfolios. Because resampling is done in blocks and with replacements, period of poor equity returns such as the Global Financial Crisis (GFC) can appear multiple times in a data sample affecting the wealth levels of equity dominated portfolios. On the other hand, vectors of good returns may also appear several times in the same time series sample enhancing returns in the equity-dominated strategy. This helps to capture a wider range of future possibilities which are derived from empirical historical data and explain the wide standard deviations in wealth estimates.

Overall, higher equity levels are good for the right tail of the distribution, providing the possibility of high terminal wealth levels for investment strategies. If the purpose of a retirement portfolio is to provide high wealth levels and generate a sustainable level of consumption in retirement, an equity dominated strategy provides a better chance of meeting this purpose. More importantly, the equity dominated strategies appear significantly better for the left tail of wealth distribution. At the lowest percentiles of the terminal wealth distribution, equity dominated and contrarian strategies provide better outcomes than traditional lifecycle strategies. This means even in bad scenarios, the retiree is better off with a strategy which has a high allocation to equities. Whilst the implementation of high equity portfolios in retirement remains a sensitive subject for any investor or adviser due to the uncertainty in financial markets, it is important to outline the benefits of such a strategy based on historical successes. The downside to these strategies, however, is that variation in the ending wealth balance as recorded by the standard deviation means it is increasingly difficult for retirement planning due to the uncertainty regarding wealth outcomes.

<Exhibit 6 Here>

The extent to which the strategies outperform each other based on the size of their terminal wealth is discussed in Exhibit 6. The analysis is not based on averages but on the actual ending values of all the simulations. The Aggressive strategy, which has an all equity allocation, significantly dominates the remaining strategies. It dominates the Growth strategy in 94% of simulations, the lowest level of outperformance observed. This level increases further with other strategies, with the highest level being 98% over the LC and Conservative strategies. The Aggressive strategy hence becomes the most dominant strategy among the eight alternative investment strategies with an overall chance of providing higher wealth levels in 24% of the total simulations.

Although the Partial LC strategy is dominated by the Aggressive Strategy, it outperforms the Growth strategy in 57% of the simulations. It also performs significantly well against the remaining strategies, dominating the LC and Conservative strategies in 98% of all simulations. Considering the total simulation of strategies, the Partial LC strategy has a 19% chance of outperforming remaining strategies. It is tied with the Growth strategy as the investment strategies providing the second highest outcomes in terms of the terminal wealth levels after 30 years of investment in retirement. The Growth strategy which retains 50 percent of the investor's wealth in equities whilst the remaining 50% is invested in conservative assets is significantly dominated by the Aggressive strategy up to 9 in every 10 simulations. It however outperforms the remaining strategies with probabilities ranging from 96% compared to the Balanced strategy to 99% for the Conservative and LC strategies.

The Reverse LC which increases equity investment over time performs better than the LC in 99% of the total simulations. This is a significant result considering the high numbers of funds which employ the lifecycle style approach as the default option. The Reverse LC also outperforms the Partial RLC and the Conservative strategies in 99% of the simulations. The Balanced strategy performs better than the Conservative, the LC and the Partial RLC at a significant a probability of 99% but performs poorly against the four remaining strategies. The LC strategy dominates the Conservative strategy in 97% of the simulations and the Partial RLC in 82%; it however, underperforms remaining strategies. Overall, the LC has a 7% chance of being the dominant strategy among the eight alternative strategies. The Conservative strategy, which contains no equities, underperforms the remaining strategies that include equities, with less than a percentage chance of dominating the other investment strategies overall.

In conclusion, while this analysis is solely based on the terminal wealth levels, we assume that irrespective of risk aversion and other preferences, a higher terminal wealth is preferred to a lower one for a retirement portfolio. The Conservative strategy underperforms all competing strategies. The inclusion of equity in the retirement portfolio improves the portfolio performance, with portfolio performance increasing with increasing equity levels; the Balanced strategy outperforms the Conservative, the Growth strategy outperforms the Balanced whilst the Aggressive strategy performs better than the Growth strategy. We find improvement in the retirement wealth levels to have a direct relation with equity levels in the portfolio. The Aggressive strategy and the Partial LC Strategies which both begin with 100% invested in equities and the Growth strategy with 70% equity investment dominate the remaining strategies in more than half of the total simulations. The desire for high levels of terminal wealth makes equity investment an attractive venture for retirees willing to take some level of uncertainty, as recorded by the standard deviation, with respect to terminal wealth. This uncertainty does not significantly impact the downside, as they remain higher than outcomes from conservative strategies. The uncertainty mainly lies in the upside potential of the portfolios, resulting in a high average and extremely high wealth levels for the right tail of the distribution. We test the impact of varying standard deviation levels for various wealth levels on the choice of strategy i.e. the trade-off between risk and return in the next section.

Whilst the equity dominated strategies are beneficial for strong upside potential and superior downside protection, they appear very volatile, affecting long term financial planning. The more conservative strategies are more stable with lower standard deviations but lower ending values. To take this into perspective, we consider strategy choice not only based on return (ending portfolio wealth) but also on the risk associated with this level of return (the standard deviation of ending portfolio wealth) using utilities based on Prospect Theory.

The expected utilities from the alternative strategies are compared at different threshold levels and ranked in order of decreasing expected utilities in Exhibit 7.

<Exhibit 7 Here>

With a zero wealth threshold, the main purpose of the retirement fund is to avoid ruin and expected utility is entirely based on terminal wealth and the risk associated with such outcome. We find the Growth and Reverse LC plans to provide higher expected utilities compared to the more conservative and more aggressive strategies. The former holds a 70 per cent asset allocation to equities whilst the latter ends with a full allocation to equities. These strategies not only have low chances of ending in negative balances but also the best performing strategies at the first percentile. The Conservative and Partial RLC strategies, although with lower standard deviations, end in lower wealth balances and have high chances of not meeting a zero balance threshold. These two represent the least preferred strategies. The ranking of alternative strategies do not change for different risk aversion and loss aversion levels. The Partial RLC dominates the Conservative strategy at all levels of the risk parameter.

When we include wealth thresholds of different levels other than zero, we find systematic changes in the expected utilities derived from the alternative strategies. At a moderate threshold of $1,000, we find the Growth strategy to dominate the alternative strategies. The Aggressive strategy is the second preferred among the strategies, and next in rank is the Reverse LC strategy. When we increase the threshold to $2,000, the Aggressive strategy dominates the Growth strategy, becoming increasingly attractive for its high ending values and higher probability of meeting the threshold. The Reverse LC is the third preferred strategy, decreasing in ranking from the previous threshold level. The Balanced strategy becomes attractive with increasing risk aversion levels, dominating the remaining strategies at a risk aversion level of 5 and higher. At a high threshold of $5,000, we find the Aggressive strategy to top the alternative strategies. The Growth strategy remains in second place, while the Partial LC and the Reverse LC strategies are the subsequently ranked strategies respectively as the threshold is increased.

Overall, using utility-of-terminal wealth approach, we find the Growth strategy to be preferred at a zero wealth threshold. The more aggressive strategies with higher equity levels are next in preference while the conservative strategies with low or no equity levels are the least preferred strategies. When we include a positive threshold to provide a minimum income level needed in retirement, we find the Growth strategy to be the preferred alternative at moderate to increasing thresholds. The Aggressive and remaining strategies with substantial equity components are preferred to the Balanced and conservative strategies. At high wealth threshold levels, the Aggressive strategy, which has a 100 percent allocation to equities, is dominant. The remaining strategies with substantial equity allocations are preferred to the Balanced, with the latter preferred to the conservative strategies. The Balanced strategy is more attractive when risk aversion increases and less attractive as the wealth threshold level increases. It decreases in ranking from third at a zero threshold to fifth with the inclusion of a positive wealth threshold. The Conservative strategy is the least preferred strategy at all threshold and risk aversion levels. At all threshold levels, the Reverse LC with an increasing equity glidepath ranks higher than the LC with a decreasing equity glidepath.

Conclusion

Investment managers seek to grow their clients' portfolios in order to meet their income and expense needs in retirement. These include meeting a sustainable income level to ensure a comfortable lifestyle or having a positive terminal wealth needed for age care costs or bequests. Our analyses show that the lifecycle approach underperforms several contrarian strategies which are more aggressive in their allocation to equities. Firstly, whilst increasing equity levels of portfolios significantly increases the terminal wealth outcome for the right tail of the distribution, it comes with a cost; a chance of portfolio ruin. When ruin occurs, however, the equity dominated portfolios perform better than more conservative portfolios in the lowest percentile of retirement terminal wealth outcomes. In terms of meeting a benchmark benefit level, in our case, an annuity equivalent, we find high equity strategies and contrarian strategies to outperform the conservative and traditional strategies. When benefit shortfall occurs, which is observed in one per cent of the simulations, the probability of severe shortfall is low. The conservative strategies however, more often are unable to meet the set benchmark benefit level.

The Lifecycle strategy, which is balanced equally between asset classes at the onset and decreases allocation to equity over time, performs better than more conservative strategies. It however underperforms its contrarian counterpart, the Reverse Lifecycle strategy, which similarly begins with a balanced allocation to the two assets but increases its equity holdings over time. The Reverse Lifecycle also outperforms the Balanced strategy. This is a simple illustration of how portfolio outcomes are improved by increasing their asset allocation to equities in retirement or having an increasing equity glidepath. This improvement in strategies with increasing equity glidepath is not absolute but depends on the portfolio starting asset allocation. The Partial Reverse Lifecycle, beginning with a full conservative asset allocation and increasing its equity allocation over time is the second worst performing strategy. The Partial Lifecycle on the other hand, fully invested in equity at the onset and decreasing over time to form a balanced asset allocation is among the top performing strategies. The starting allocation of investments matter and is an important determinant of the equity glidepath effect.

Finally, considering the utility-of-terminal wealth approach which enables a wealth threshold input involves setting a minimum wealth threshold and penalising themselves for wealth levels below this threshold. When the strategy aims to leave a positive wealth and the only risk is to guard against portfolio ruin, the Growth strategy is the preferred. The Reverse Lifecycle approach is the second preferred strategy. These two strategies are also the best performers in the worst case scenarios, when retirement outcomes are at their lowest. The Aggressive strategy becomes more attractive at low positive wealth thresholds, dominating the remaining alternatives at thresholds exceeding the starting level. At all wealth thresholds, strategies with substantial equity allocations are preferred to strategies with low equity allocation.

As baby boomers move from the accumulation phase to the decumulation phase, it is necessary to develop more sophisticated models that will help investors meet their retirement needs. In this era of market uncertainty and low yields on bonds and cash, such a model should be able to provide returns to grow retirement wealth and provide adequate income for a comfortable retirement. The failure of the Lifecycle strategy to compete with alternative strategies illustrates the need for growth in retirement wealth. While reliance on safe assets in retirement investment may be appealing to risk-averse individuals, overreliance on conservative assets and lifecycle approach may be detrimental for retirement outcomes. The conservative strategies are unable to withstand the stress of periodic income withdrawal demands especially as we experience elongated lifespans. Alternatively, contrarian strategies such as reverse lifecycle strategies are able to take advantage of the market movements whilst remaining relatively stable and providing better retirement outcomes and decreased chances of portfolio ruin.

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EXHIBITS

Exhibit 1: Ruin Probabilities for Alternative Strategies

This exhibit illustrates the instances of ruin for the alternative investment strategies. The probabilities of ruin for show rates ranging between 3%-7% of initial wealth rate adjusted for inflation in subsequent withdrawal. LC represents the Lifecycle strategy, PLC represents the Partial LC, PRLC denotes the Partial Reverse LC, RLC denotes the Reverse LC strategy.

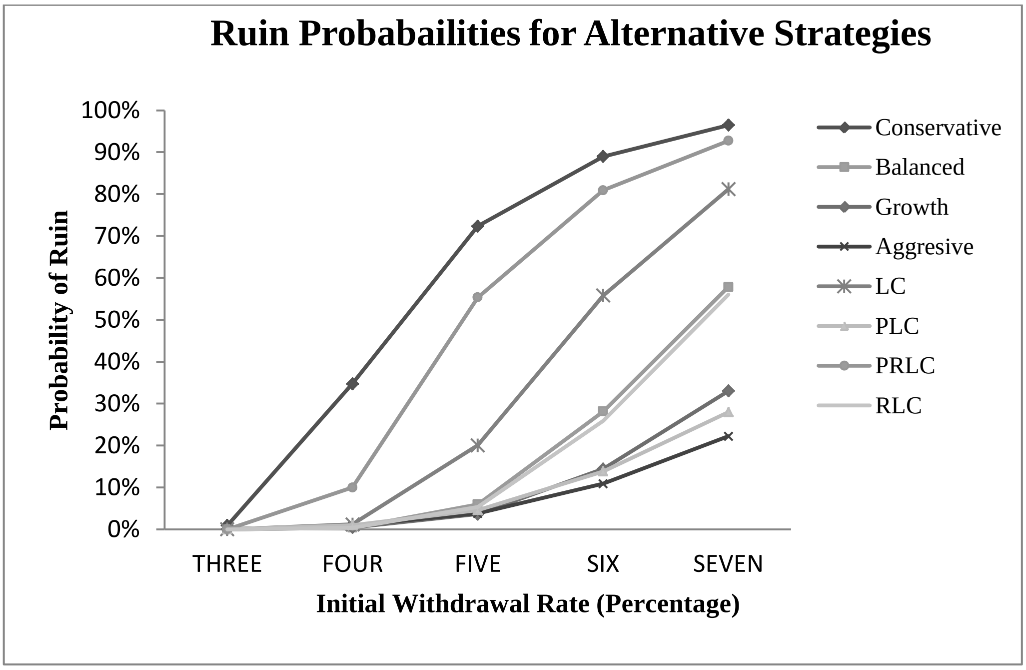

Exhibit 2: Extent of Portfolio Ruin

This exhibit presents the shortfall analysis with regard to portfolio ruin. For each of the eight strategies, this exhibit shows the Mean Shortfall (in years), Exceeding Shortfall, which is the number of simulations resulting in ruin levels exceeding the Mean Shortfall and the Maximum shortfall levels for the range of initial withdrawal levels. LC represents the Lifecycle strategy, PLC represents the Partial LC, PRLC denotes the Partial Reverse LC and RLC denotes the Reverse LC strategy.

		Conservative	**Balanced**	**Growth**	**Aggressive**	**LC**	**PLC**	**PRLC**	**RLC**
3%	Mean Shortfall (Years)	1	0	0	3	0	2	0	0
	Exceeding Shortfall (Number)	38	0	0	3	0	2	0	0
	Maximum Shortfall (Years)	4	0	0	9	0	5	0	0
4%	Mean Shortfall (Years)	3	2	4	5	2	4	2	2
	Exceeding Shortfall (Number)	1623	17	17	41	53	37	446	17
	Maximum Shortfall (Years)	10	7	11	15	6	14	8	6
5%	Mean Shortfall (Years)	7	4	5	7	3	6	6	4
	Exceeding Shortfall (Number)	3965	258	169	191	888	208	2888	230
	Maximum Shortfall (Years)	14	12	14	18	12	17	12	11
6%	Mean Shortfall (Years)	10	6	6	8	6	7	9	6
	Exceeding Shortfall (Number)	5262	1347	670	525	2715	662	4671	1221
	Maximum Shortfall (Years)	16	16	18	20	15	20	15	16
7%	Mean Shortfall (Years)	13	8	8	9	9	9	12	8
	Exceeding Shortfall (Number)	6165	2957	1644	1097	4378	1357	5849	2856
	Maximum Shortfall (Years)	18	18	19	21	17	20	18	18

Exhibit 3: Income Shortfall Probabilities

This exhibit shows the probability that income generated from the terminal wealth from the different strategies after 20 years is less than the expected income from the benchmark life annuity purchased at retirement age, given different Initial Withdrawal Rates (IWR). LC represents the Lifecycle strategy, PLC represents the Partial LC, PRLC denotes the Partial Reverse LC and RLC denotes the Reverse LC strategy.

I.W.R	Conservative	Balanced	Growth	Aggressive	LC	PLC	PRLC	RLC
3%	29%	0%	1%	1%	1%	1%	9%	0%
4%	58%	3%	2%	2%	9%	3%	39%	3%
5%	78%	13%	7%	6%	31%	7%	68%	12%
6%	89%	34%	18%	14%	58%	17%	84%	33%
7%	95%	58%	34%	24%	79%	28%	93%	57%

Exhibit 4: Extent of Income Shortfall

This exhibit shows the extent of shortfall for the alternative strategies relative to the benchmark life annuity level. It illustrates the number of hypothetical retirees (simulations) and the extent of shortfall for the alternative strategies. For each pair of strategies, the strategy with higher equity allocations is represented by the red solid lines and the blue dashed lines for the lower equity allocated strategies. LC represents the Lifecycle strategy, PLC represents the Partial LC, PRLC denotes the Partial Reverse LC and RLC denotes the Reverse LC strategy.

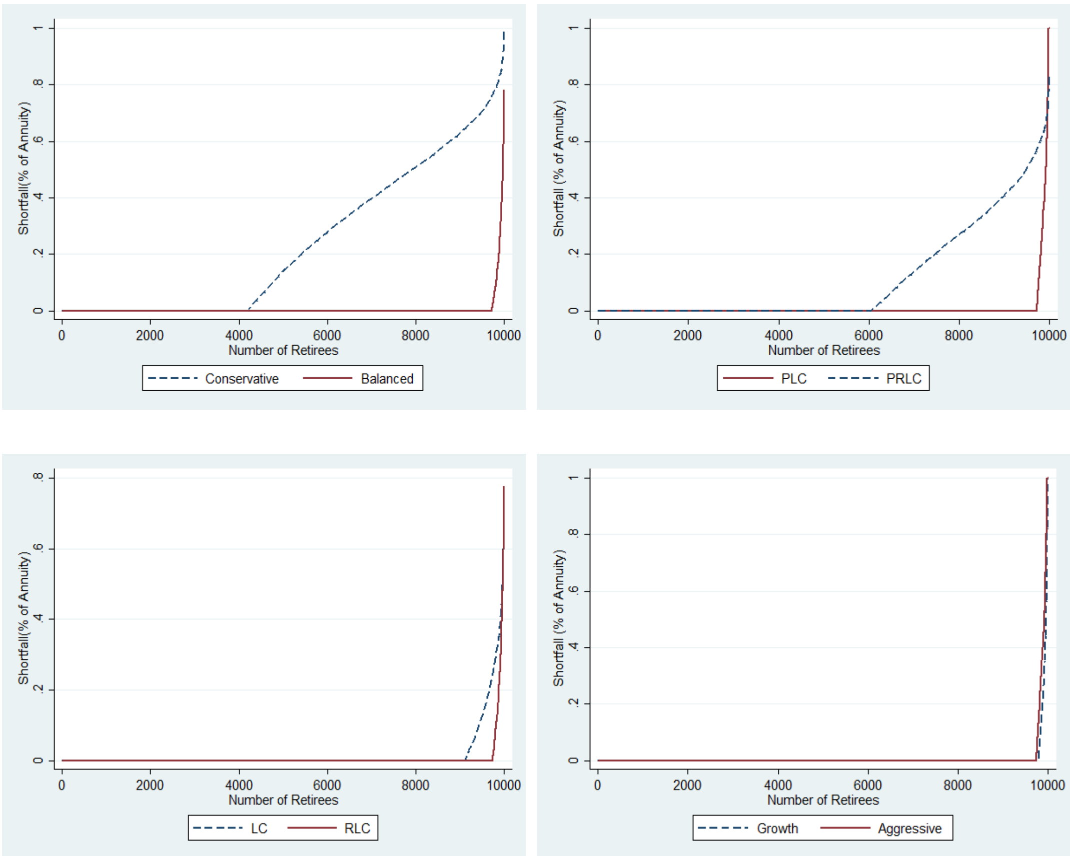

Exhibit 5: Summary Statistics

This exhibit presents the summary statistics for the eight post-retirement strategies analysed. It shows the average ending portfolio averages for the 10,000 simulations, the median wealth terminal wealth level, standard deviation of terminal wealth, as well as different percentile distributions of the terminal wealth at 4% initial withdrawal rate. LC represents the Lifecycle strategy, PLC represents the Partial LC, PRLC denotes the Partial Reverse LC and RLC denotes the Reverse LC strategy.

	Average	**Median**	**SD**	**1st**	**5th**	**10th**	**75th**
Conservative	802	342	1,526	-822	-608	-470	1,294
Balanced	6,409	5,151	5,037	377	1,312	1,909	8,130
Growth	11,601	9,177	9,642	465	2,009	3,130	14,665
Aggressive	20,390	15,080	19,461	127	2,358	4013	25,920
LC	2,893	2,223	2,532	-40	368	653	3,743
PLC	11,858	9,458	10,048	4	1,701	2,874	15,145
PRLC	1,965	1,283	2,334	-516	-202	0	2,734
RLC	7,629	6,020	6,212	448	1,484	2,176	9,690

Exhibit 6: Comparing Performance of Alternative Strategies

This exhibit shows a comparison of performance among the alternative strategies based on the size of terminal wealth levels and a 4% initial withdrawal rate over the investment period. It shows the chances of each of the eight strategies outperforming competing strategies. The probabilities represent the chances of the rows outperforming the columns (Columns underperforming the rows). Our performance measure is based on terminal wealth levels in 10,000 simulations. The final column titled Overall measures the chance of a strategy dominating the remaining strategies in the total number of simulations. Agg denotes the Aggressive strategy, LC represents the Lifecycle strategy, PLC represents the Partial LC, PRLC denotes the Partial Reverse LC and RLC denotes the Reverse LC strategy.

	Cons	Bal	Growth	Agg	LC	PLC	PRLC	RLC	**Overall**
Conservative	0.00	0.01	0.01	0.02	0.03	0.02	0.01	0.01	**0.00**
Balanced	0.99	0.00	0.04	0.05	0.99	0.09	0.99	0.17	**0.12**
Growth	0.99	0.96	0.00	0.06	0.99	0.43	0.98	0.97	**0.19**
Aggressive	0.98	0.95	0.94	0.00	0.98	0.95	0.97	0.96	**0.24**
LC	0.97	0.01	0.01	0.02	0.00	0.02	0.82	0.01	**0.07**
PLC	0.98	0.91	0.57	0.05	0.98	0.00	0.96	0.89	**0.19**
PRLC	0.99	0.01	0.02	0.03	0.18	0.04	0.00	0.01	**0.05**
RLC	0.99	0.83	0.03	0.04	0.99	0.11	0.99	0.00	**0.14**

Exhibit 7: Ranking of Alternative Strategies based on Utility of Terminal Wealth

This exhibit presents the ranking of alternative strategies for different Relative Risk Aversion levels in the first column and different terminal wealth threshold levels in the subsequent columns. We rank the eight alternative investment strategies based on the expected utilities derived from terminal wealth given a 4% initial withdrawal rate over the investment period. The strategies are represented by numbers 1-8 as shown below the table.

RRA\THRESHOLD	$0	$1,000	$2,000	$5,000
2	3,8,2,6,4,5,7,1	3,4,8,6,2,5,7,1	4,3,6,8,2,5,7,1	4,3,6,8,2,5,7,1
3	3,8,2,6,4,5,7,1	3,4,8,6,2,5,7,1	4,3,6,2,8,5,7,1	4,3,6,8,2,5,7,1
5	3,8,2,6,4,5,7,1	3,4,8,6,2,5,7,1	2,4,3,6,8,5,7,1	4,3,6,8,2,5,7,1

1	Conservative
2	Balanced
3	Growth
4	Aggressive
5	LC
6	PLC
7	PRLC
8	RLC