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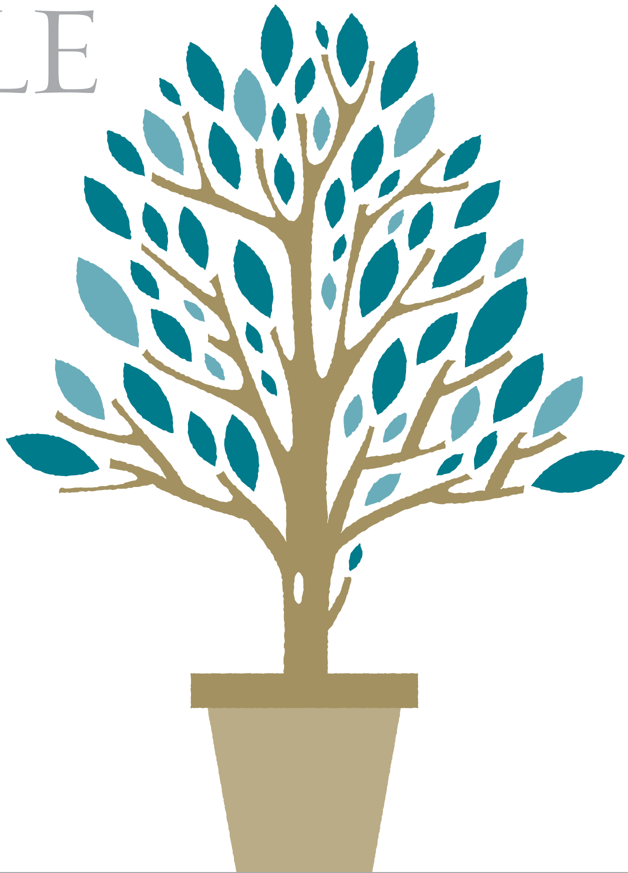
SEQUENCING RISK
A KEY CHALLENGE TO CREATING SUSTAINABLE *retirement income*



RESEARCH REPORT

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FOREWORD

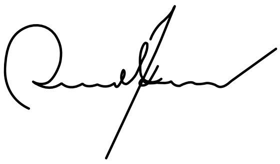
If market risk were not challenging enough for superannuation funds, this important and unique research finds that the sequence in which returns are realised by investors plays a critical role in determining the sustainability of retirement incomes.

Samuel Taylor Coleridge once described poetry as ‘the best words in their best order’. Many acclaimed poets throughout history have mastered the craft of arranging or sequencing words in such a way that their poetic quality lingers with us long after reading the final word of a poem. But what happens when one cannot control the arrangement of the words or, for purpose of this study, the sequence of events? Over the past decade, this has been the case for defined contribution (DC) plan members whose retirement savings have experienced a path of events (including the dot.com crash, the subprime crisis, the global financial crisis and the European debt crisis) that arguably could be described as ‘the worst returns in their worst order’.[1]

One of the lessons from this extraordinary period of financial history is that the level of retirement savings (and, subsequently, retirement income) is not only a function of the investment returns in every period but also the realised sequence of these returns throughout life.

Sequencing risk becomes more important as the portfolio size increases and is particularly acute during the retirement conversion phase (say, the final 15 years of working life and the first 10 years of retirement).

Using historical and bootstrap simulation from Australian data, this study finds that sequencing risk has a pervasive influence on the sustainability of retirement income and this risk is particularly acute around the period in which retirement savings are at their peak.



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1. As shown in the historical simulation section of this study, some 40-year investment horizons over the past century (particularly those ending in the 1970s) were acutely affected by sequence of returns risk.

CONTENTS

FIGURES AND TABLES

OVERVIEW

Sequencing risk adds to the range of important risks faced by members of defined contribution superannuation funds in Australia. With increasing numbers of baby boomers entering the 20–25 year conversion phase from retirement savings into retirement income, the sequence of returns risk is a current and significant challenge both for fund members and policy makers. Many investors are unaware that the sustainability of their retirement income largely is determined not by the average return of their investments, but the realised sequence of those returns.

Australia's retirement saving system, known as superannuation, is dominated by defined contribution (DC) plans. A recent study by Towers Watson (2011) reported that in 2010, around 80 per cent of all pension assets in Australia were held by DC plans (compared with 57 per cent in the United States of America (US), 40 per cent in the United Kingdom (UK) and only 2 per cent in Japan).[2] This defining feature of the Australian system has led to much debate about the risks faced by DC plan members and the systemic and idiosyncratic features of the system. Two key reports recently commissioned by the Australian Government, the Cooper[3] and Henry[4] reviews, make important contributions to the debate highlighting the need for further product innovation to assist members with mitigating investment, longevity and inflation risk.[5]

Sequencing risk is a further risk for DC plans, which is sometimes hidden from direct view and this research seeks to frame this risk more formally for all stakeholders in superannuation, particularly fund members. The paper highlights that sequencing risk is a pervasive factor, which is constantly encountered by DC plan members and becomes particularly acute during the critical retirement conversion phase (that is, late accumulation and early decumulation).

The first of the baby boomer cohort turned 65 years of age in 2011. The final decade of their investing journey included the aftermath of the dot.com collapse, the 9/11 terrorist attacks, the invasions of Iraq, the subprime mortgage crisis, the global financial crisis, Madoff Ponzi scandal, the European debt crisis and the US downgrade to AA+. This highlights the extent to which the sequence or ordering of events plays a critical role in the sustainability (or otherwise) of retirement savings and, ultimately, retirement income.

The key finding of this study is that the average of accumulated investment returns is not necessarily the key driver of retirement outcomes. Rather, it is the sequence of these returns that is paramount. If someone encounters the sequence of returns observed in the first decade of the twenty-first century quite early in their career, say in their twenties, they have time to recover from these relatively low returns over the next four decades of their working life. However, for someone who is 60 years of age and whose retirement outcomes are largely driven by investment returns, experiencing this sequence of returns over the final decade of their working life leads to a vastly different outcome. Unlike the younger investor, the 60-year-old does not have the time to recover from these investment losses through gains made on future contributions, resulting in a fall in the adequacy of retirement savings and heightened longevity risk.[6]

In recent years, a variety of definitions have been developed to capture the essence of sequencing risk. While all definitions face limitations, it is important to note the context in which the definition is formulated (particularly those originating from countries where defined benefit (DB) plans dominate).

Some of the key definitions of sequencing risk in recent years have included:

> 'Sequence of returns risk is an investment risk that only affects investors who are actively drawing income from their investment portfolios' (Eszes 2010). This definition limits sequencing risk to the decumulation phase and does not consider the risk during the accumulation period (largely because of a DB-based system).

2. It is important to note that the current state of play is nothing new for Australia, with DC plans holding 78 per cent of total pension assets in 1999. The proportion of pension assets held by DC plans was: US (44 per cent); UK (5 per cent); and Japan (negligible), (Towers Watson 2011).

3. *Australia's Super System Review: Final Report* (the Cooper Review) is available at: www.supersystemreview.gov.au/. Note from the report, the statement that 'a number of industry participants have turned their minds to the challenge of product innovation in the post retirement phase. The broad theme of these developments has been to explore ways to better manage the key risks (investment, longevity and inflation) to which people are directly exposed in the account-based pension framework'.

4. These themes, particularly related to issues of longevity risk, are supported by *Australia's future tax system: report to the Treasurer* (the Henry Review) available at: http://taxreview.treasury.gov.au/content/Content.aspx?doc=html/home.htm. The report notes 'the current retirement income system does not provide the products that would allow a person to manage longevity risk. This is a structural weakness'.

5. For an international perspective, see the Organisation for Economic Co-operation and Development (OECD) report by Antolin et al. 2010.

6. There is an important body of literature that considers the value of transferring risk from a corporate defined benefit (DB) plan to a DC plan. A key contribution by Milevsky (2007) examined companies which were undergoing a transition from DB to DC plans at an average of one company a month for the period 2001 through to mid-2007. Milevsky (2007) found that these companies experienced an average risk-adjusted abnormal return of around four per cent during the 10 trading days before and after the announcement of this information to the market.

- 'Investors in any phase are vulnerable to the market's random gyrations, but investors in the distribution phase are even more sensitive to unfortunate timing. They may retire at a favorable time in the market or during a highly unfavorable period' (Jones 2007). Again, this definition predominantly focuses on the decumulation or distribution phase; however, the vulnerability to sequencing risk 'in any phase' is acknowledged.
- 'Sequencing risk has to do with the (bad) risk of needing to pull money out of a portfolio during a particularly poor performance year and the (good) risk of being able to add money during a down year' (Minor 2011). This definition is particularly interesting as it incorporates both 'bad' and 'good' elements of sequencing risk. While applicable across one's investing life, the dynamic nature of the risk needs further exploration.
- 'What's more important to your clients, rate of return or order of return? The gut reaction of nearly every financial adviser is rate of return. But for your clients in the second half of their financial lives, I argue that order of returns (also known as the sequence of returns) is every bit as important as rate, and is potentially the biggest retirement risk of which your clients are unaware' (Neuman 2011). This definition highlights one of the key ideas in the sequencing risk debate. Investors would prefer the lowest rates of return when they have the smallest account balances (the early years). As portfolio balances grow larger and retirement comes closer, larger returns are desired (Neuman 2011).

The worst returns in their worst order

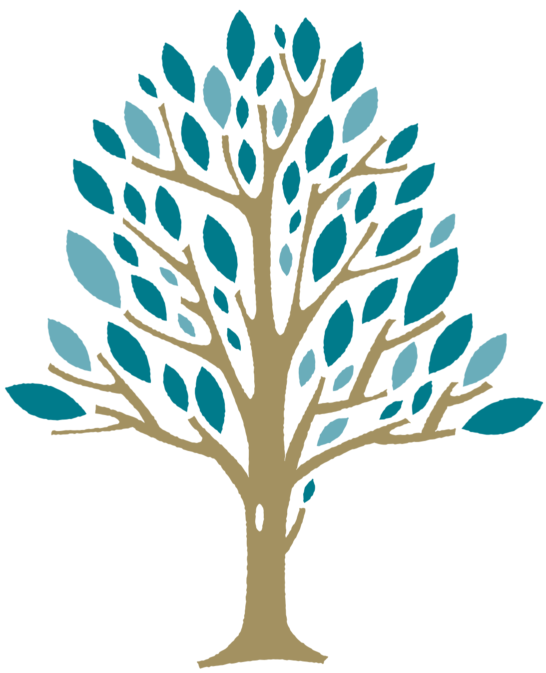
For the purposes of the study, the working definition of sequencing risk is the *worst returns in their worst order*. It is suggested that in a DC framework, sequencing risk emerges right from the point when the second contribution is made to the member's account. As portfolio size grows with multiple contributions and the accumulation of returns, the risk becomes more acute over time. The growth in portfolio size is driven by multiple cash inflows to the portfolio both in terms of contributions and investment returns, with the latter usually accounting for an increasingly larger proportion of the portfolio balance over time. As such, sequencing risk is prevalent both in the accumulation and decumulation phases of a member's investing life and, by definition, occurs well before a DC plan member's retirement date.

In short, sequencing risk is the risk of experiencing returns in an unfavourable order during periods facing changes in invested capital, either through contributions or distributions. The unfavourable order is observed when large negative returns are experienced during the period with the greatest portfolio balance (that is, the worst returns in their worst order).

As investigated empirically, the key factors influencing sequencing risk are: the size of the contributions (or withdrawals); the growth of the contributions (or withdrawals) through time; the timing of contributions (or withdrawals); the portfolio balance and the return volatility. Given Australia's DC plan heritage, this research focuses on the accumulation phase (that is, up to the retirement date) to highlight the emergence of sequencing risk from a DC plan member's perspective, not simply considering the issue at the decumulation/distribution phase (which takes more of a DB plan perspective).

For DC plan members, sequencing risk grows with the portfolio balance — as the portfolio (or retirement nest egg) increases in size, the variation that can occur in the dollar value of this portfolio also increases. This idea has been described by Basu and Drew (2009a) as the 'portfolio size effect'.

The key determinant of retirement outcomes in DC plans is the interplay between portfolio size effect (what you do when the largest amount of your money is at risk matters; that is, during the retirement conversion years) and the related problem of sequencing risk. In short, poor returns in a bear market may not be anywhere near as important as the timing of the loss, especially over the conversion phase.



1. WHAT DRIVES SEQUENCING RISK?

Investors walk a constant tightrope in seeking to take a prudent amount of risk at every stage of their working lives. Too little risk and one will fall short of the promise of endless summers; too much risk can deplete retirement savings to a point which it may never recover (Doran, Drew and Walk 2012). There are a limited number of approaches to investigating the drivers of sequencing risk.[7] These methods invoke the ceteris paribus assumption (that is, assuming all else is equal) to consider the impact of sequencing risk on retirement savings. This study uses both historical simulation (that is, actual 40-year historical investment returns paths from 1900 to 2011) and a bootstrap approach (that is, a sampling approach that allows sequencing risk to be considered for possible future paths that are simulated from the empirical distribution of returns) to investigate sequencing risk from the perspective of a DC plan member in Australia.

Before commencing an empirical analysis of sequencing risk, the data and methodological approach of the study need to be considered. It is known that contributions are a key driver in determining retirement outcomes. In order to consider these outcomes through the prism of sequencing risk, a simple, hypothetical DC plan member who was born on 1 January 1987 was developed. The member commenced their working life this year, at 25 years of age (1 January 2012) with a targeted retirement at 65 years of age (1 January 2052). Table 1 outlines the key assumptions attributed to the hypothetical DC plan member, with figure 1 illustrating their assumed nominal cumulative contributions over the 40-year accumulation period.[8, 9]

Table 1 outlines the key assumptions attributed to the hypothetical DC plan member, with figure 1 illustrating her assumed nominal cumulative contributions over the 40-year accumulation period.[9,10]

It is important to note that, throughout this study, the analysis commenced as at 1 January 2012 and considered the impact of various return paths (historical and simulated) over the hypothetical DC plan member's accumulation phase. Nominal contributions (and nominal returns, as discussed below) are used to consider the impact of different sequencing on retirement outcomes. These simplifying, present-day assumptions regarding starting salary, salary growth rates, contribution rates and retirement age, in concert with nominal returns, allow for the variable of interest — accumulated savings in a DC plan — to be a function of the sequence of returns.

The data used in this study comes from the Dimson Marsh Staunton (DMS) (2002) database and represents nominal annual returns for 112 years from 1900 to 2011.[10] This long-run data allows the study to examine a large number

Table 1: Key assumptions

VARIABLE	ASSUMPTION
Starting balance	$0
Starting salary	$41,552*
Salary growth rate	4% p.a.
Contribution rate	9% p.a.
Starting age	25 years**
Retirement age	65 years

* Average MyCareer minimum starting salary across all sectors as at end-April 2012.

** First contribution made at end of first year (that is, 1 January 2013), final at end of final year (that is, 1 January 2052), contributions experience 40 years of returns though investment horizon is 41 years.

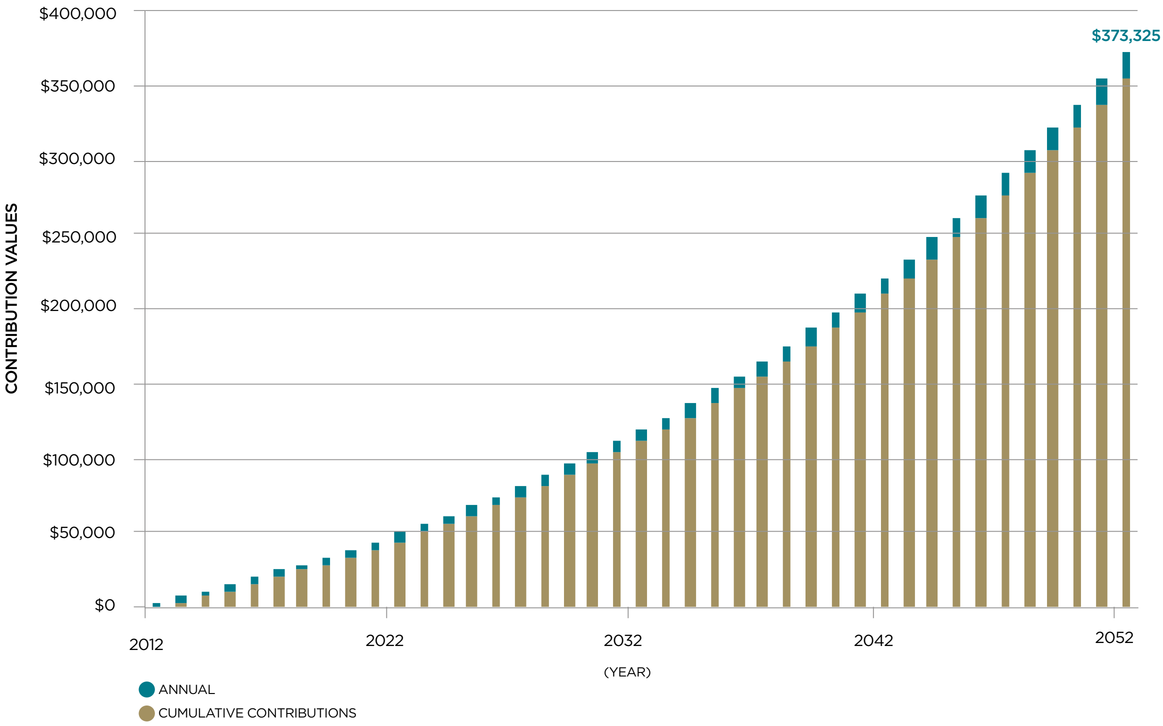
7. See Milevsky and Abaimova (2008); Milevsky (2009); and Milevsky and Macqueen (2010).

8. The main body of the study considers nominal returns and contributions to investigate sequencing risk. This is because returns being earned by DC plan members are nominal in nature (and, as accumulated returns, coupons and dividends are paid in nominal terms). The use of nominal returns has precedent in the broader pensions literature (see, for example, Hickman et al. 2001; Guo and Darnell 2005; Basu and Drew 2009a; and Basu, Byrne and Drew 2011) and retirement wealth ratios (RWRs) are reported that allow future nominal retirement outcomes to be based on the final nominal salary of our hypothetical DC plan member. However, it is acknowledged that using real returns and contributions would provide a useful confirmatory analysis through which to consider the impact of sequencing risk. Appendix 3 undertakes an identical methodology to that reported in the main body of the study (but using real returns and contributions), corroborating the key results and providing further practical insights into sequencing risk from an inflation-adjusted perspective.

9. It is acknowledged that these are simplifying assumptions. There are a number of possible salary growth trajectories that could have been considered (for example, Byrne et al. 2006 show a humped profile for men and women in the UK) associated with gender and career breaks (see Basu and Drew 2009b), the casualisation of the workforce (Pocock 2003), housing and superannuation (Davis 2007), and the role of human capital (Merton 1969). The challenge with all such modelling is that a trade-off between 'real-world features' and building a simple model that allows us to consider the interplay between terminal wealth (dependent, or y variable) and sequencing risk (independent, or x variable) is faced. For example, it is known that many people 'back-load' voluntary contributions into their DC plan late in their career. As such, a constant increase that possibly underestimates salary growth early in the career, but attempts to incorporate potential back-loading of contributions later in the career, is allowed. It is noted that further research in this area is an important next step in the development of DC plan literature.

10. The DMS database lists real returns for the period 1900 to 2011 (n = 112). Australian stocks, bonds and bills are listed in AUD. The real returns for US stocks and bonds are reported in USD and converted into AUD returns using the exchange rate return provided by DMS. All returns are converted into nominal returns as the study uses nominal values for salary growth. The database is available commercially from Morningstar.

Figure 1: Cumulative contributions of a hypothetical DC plan member using assumptions from table 1



(n = 73) of overlapping (1900–1939, 1901–1940 ... 1972–2011) 40-year paths through to 2011 in the historical simulation and provides a rich source of data for the bootstrap approach.

In order to 'generate' investment returns, some assumptions regarding asset allocation were made. The vast majority of Australians (that is, around 80 per cent) are enrolled in the default option of their superannuation fund, and that these predominantly target risk in nature, with around two-thirds allocated to growth assets (Towers Watson 2012). The growth-oriented nature of default options in Australia is confirmed by the Australian Prudential and Regulation Authority (APRA) (2012) asset allocation data on the default investment strategy of Australian superannuation funds (as at 30 June 2011).

A common problem facing DC plan researchers internationally is how to convert the actual default asset allocation (which includes not only stocks, bonds and bills, but also unlisted property, private equity, infrastructure, alternatives and more) to develop a proxy asset allocation that allows long-run analysis.[11]

The methodological approach of Basu and Drew (2009a); and Basu, Bryne and Drew (2011) is followed and the following assumptions regarding the default asset allocation strategy employed in this study are made:

- 'Other assets' are assumed to be made up of growth assets. The 13% is divided into 'Australian shares' and 'international shares'; seven per cent and six per cent, respectively.
- 'Listed property' and 'unlisted property' is assumed to have similar properties to fixed interest assets. 'Australian fixed interest' is allocated six per cent of the combined 10%, while 'international fixed interest' is allocated the remaining four per cent.
- 'International shares' and 'international fixed interest' use US equities and bonds (converted into AUD), respectively, as a proxy for international investments in the default strategy. Figure 3 illustrates the default strategy used in this study.[12]

Given long-run data restrictions, a five-asset portfolio that is target risk in nature and rebalanced annually is constructed. No taxes, fees or transaction costs are assumed in this analysis.[13] As with current practice, the default

11. For a more detailed discussion on this procedure see Basu and Drew (2010).

12. It is important to note that *very basic proxies* for the default position of Australian superannuation funds as they exist today are used. Given that the research motivation is to consider the sequence of returns risk over long horizons in Australia, long-run historical data (with an annual frequency) is used. Therefore, as with other papers considering the potential long horizon performance of defined contribution plans, this study sacrifices the opportunity to select more precise proxies for various asset classes (for instance, it would perhaps be advantageous to use a monthly MSCI World Index ex Australia hedged in AUD as a proxy for international shares. The trade-off is that this index was only launched on 31 December 1969, compared with the 1900 start date for the DMS data).

13. It is acknowledged that the tax treatment of contributions and investment earnings, and the impact of costs, are important issues worthy of future research consideration. It is noted that taxes are levied on a nominal basis, further supporting the use of nominal contributions and returns in this study.

Figure 2: Asset allocation of the default investment strategy in Australia

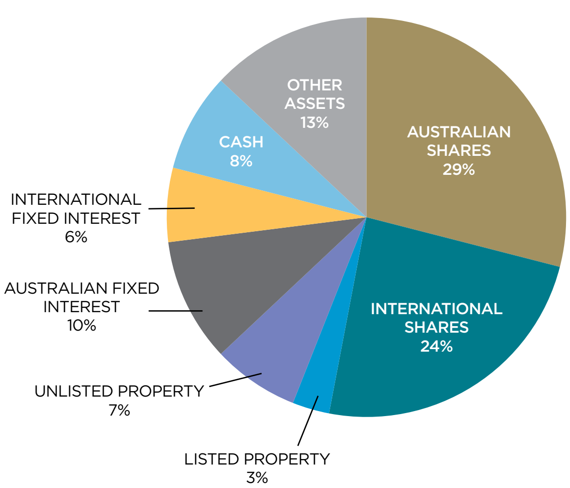
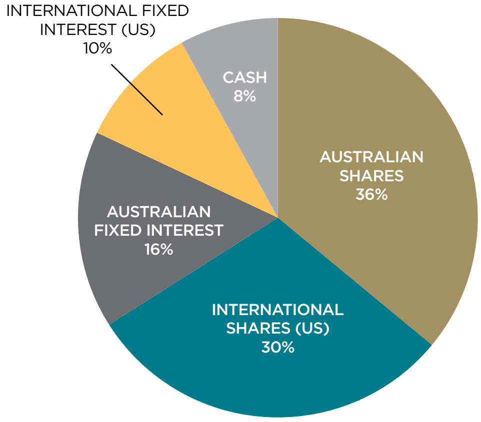


Figure 3: Asset allocation of the default strategy used in this study



growth assets (66/26/8 stocks/bonds/bills allocation, or 66/34 growth/income), reflecting the growth-oriented asset allocation that is applied in the DC plans of the vast majority of Australians. Table 2 provides summary statistics for the investment returns from such a default strategy from 1900 to 2011.

Table 2: Summary statistics for the default strategy (1900–2011)

VARIABLE	ASSUMPTION
Mean	10%
Standard deviation	11%

As discussed previously, when the proportion of retirement savings dwarfs future expected superannuation contributions, the ordering or sequencing of returns becomes a key driver of outcomes for DC plan members. By way of simple example, taking the hypothetical member who commenced in the workforce on 1 January 2012, recall that her first contribution to superannuation will be made on 1 January 2013. It is assumed that the most recent 40-year return path (1972–2011) repeats again for 2013–2052, when the member retires at 65 years of age. Now, imply reverse the order of returns and create a new 40-year return path for the member (2011–1972). It is important to note that, as shown in Table 3, the two return paths have identical return distributions (all four moments are identical) as they depict the same returns, just in a different order — reversed to be precise (exposing the superannuation portfolio to a specified amount of risk). Table 3 also shows the most extreme sequencing paths for 1972 to 2011 in which the DC plan member experiences returns from worst to best (ascending order) and best to worst (descending order), respectively.

Merely reversing the order in which returns are experienced, 2011–1972 as opposed to 1972–2011, yields two very different accumulation outcomes: $4.0 million (1972–2011) and $5.4 million (2011–1972), a material difference of $1.4 million or around 35 per cent. Interestingly, this difference of $1.4 million is around four times the total (or lifetime) nominal contributions made by the member to 2052 (of around $373,000). Figure 4 gives a glimpse of the potential impact of this largely hidden, but pervasive factor, known as sequencing risk.

A DC plan accumulation path can be thought of as being broken up into multiple superannuation contributions, which track their own return path through time. The first contribution experiences every return the portfolio experiences. Subsequent contributions are not affected by previous returns, but only by future returns. With this framework, it can be seen that future returns affect a greater number of contributions. Hence, when the size of the superannuation nest egg exceeds future expected contributions, the returns occurring late in the accumulation phase (and early in the decumulation or distribution phase) have the largest impact.

Although much of the emphasis in the debate about sequencing risk casts it as a negative risk, like standard deviation it can also have a positive impact. Intuitively, the two extremities of sequencing risk — downside and upside — or 'bad' and 'good' risk, can be observed. Downside (upside) sequencing risk arises when the most negative (positive) returns are being experienced and when the most contribution paths (and thus the largest amount of money) are being affected by the return. Ordering the returns from largest (smallest) to smallest (largest) provides the extreme downside (upside) of a path of returns. Figure 5 illustrates these extreme outcomes

Table 3: Annual returns for the default strategy for the 40-year period from 1972 to 2011

	ACTUAL (1972–2011)	REVERSED (2011–1972)	BEST (ASCENDING)	WORST (DESCENDING)
	14%	3%	-22%	42%
	-22%	3%	-12%	40%
	-12%	10%	-10%	35%
	35%	-10%	-10%	32%
	20%	6%	-8%	31%
	7%	11%	-3%	30%
	14%	15%	-2%	28%
	27%	15%	-2%	27%
	23%	4%	3%	26%
	-3%	-8%	3%	25%
	17%	5%	4%	23%
	40%	11%	5%	20%
	9%	10%	6%	18%
	42%	18%	7%	17%
	32%	30%	8%	15%
	-2%	11%	9%	15%
	8%	28%	10%	14%
	25%	-10%	10%	14%
	-2%	26%	10%	11%
	31%	10%	11%	11%
	10%	31%	11%	11%
	26%	-2%	11%	10%
	-10%	25%	14%	10%
	28%	8%	14%	10%
	11%	-2%	15%	9%
	30%	32%	15%	8%
	18%	42%	17%	7%
	10%	9%	18%	6%
	11%	40%	20%	5%
	5%	17%	23%	4%
	-8%	-3%	25%	3%
	4%	23%	26%	3%
	15%	27%	27%	-2%
	15%	14%	28%	-2%
	11%	7%	30%	-3%
	6%	20%	31%	-8%
	-10%	35%	32%	-10%
	10%	-12%	35%	-10%
	3%	-22%	40%	-12%
	3%	14%	42%	-22%
Mean	**12%**	**12%**	**12%**	**15%**
Standard deviation	**15%**	**15%**	**15%**	**15%**
Skewness	**-0.04**	**-0.04**	**-0.04**	**-0.04**
Excess kurtosis	**-0.28**	**-0.28**	**-0.28**	**-0.28**
Terminal wealth	**$4.0m**	**$5.4m**	**$17.4m**	**$1.4m**

using the same historical path (1972–2011) reordered for the hypothetical member. Figure 5 illustrates the extreme outcomes for sequencing risk for a single historical path from 1972 to 2011. The difference between the two paths is around $17.4 million or 46 times total lifetime contributions. The upside sequencing risk path has actually beaten the downside sequencing risk path by a factor of 12 times. While it is conceded that these outcomes are unrealistic (as extreme scenarios are), they provide another insight into the potential impact of sequencing risk on a portfolio. Perhaps the key lesson to be learned is that when investment returns and performance results for members of DC plans focusing on the four moments of the distribution (and typically, the emphasis is on the first moment, the average return) are presented, it is important to understand that the historical shape of the distribution of investment returns, not its order, is being described.

Figure 4: Wealth accumulation paths for two return paths: (1972–2011) and the reverse (2011–1972)

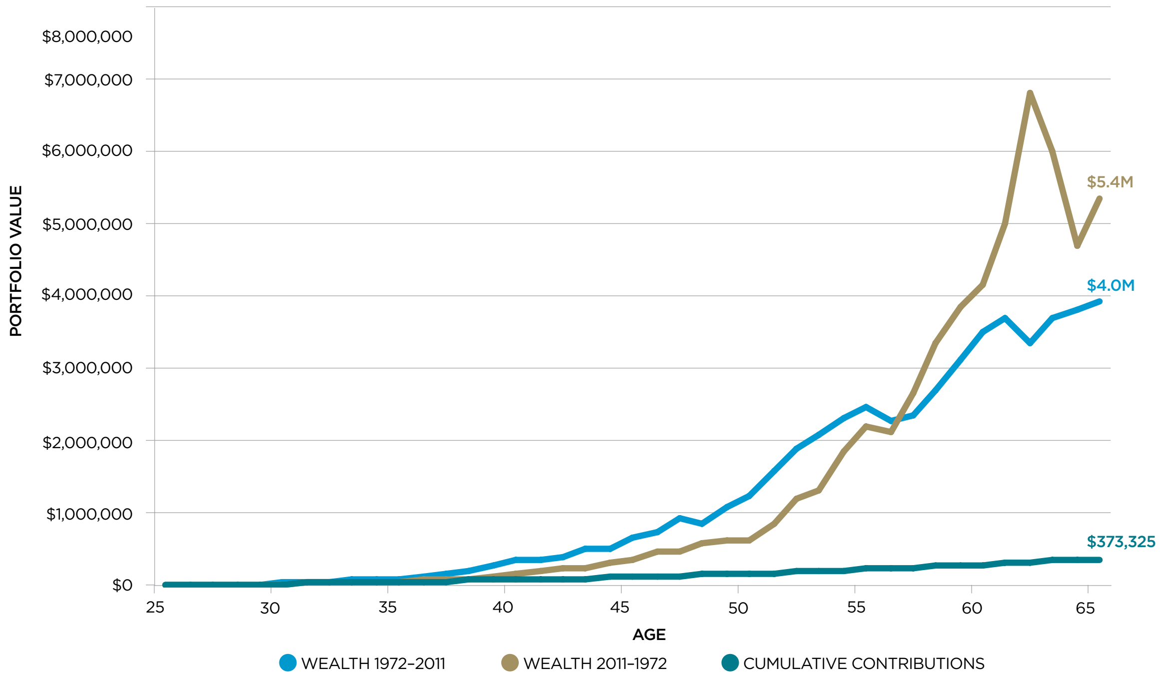
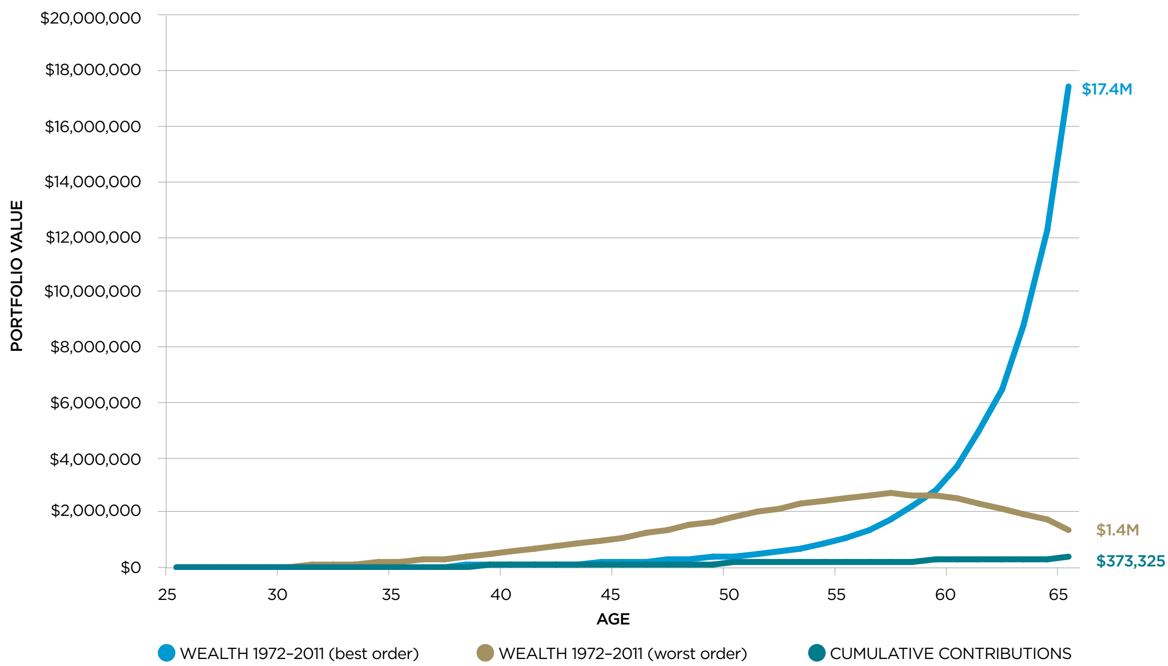


Figure 5: Wealth accumulation paths for the best (smallest to largest) and worst (largest to smallest) ordered returns of the default strategy from 1972 to 2011



2. WHEN IS SEQUENCING RISK A PROBLEM?

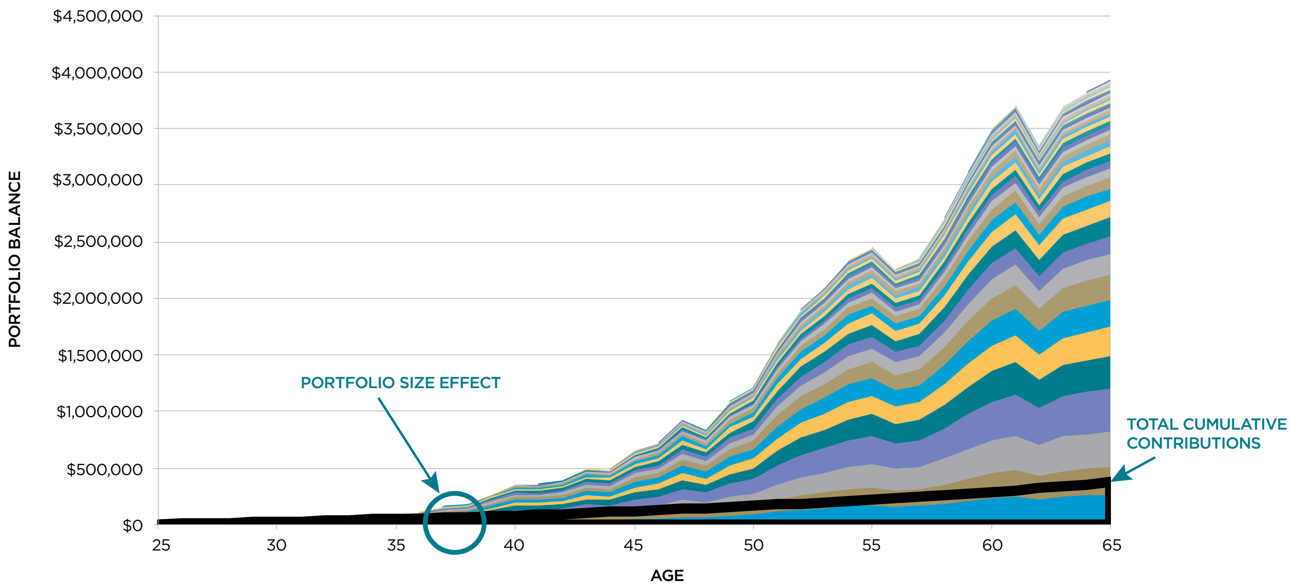
Sequencing risk becomes more acute as the size of the DC portfolio increases and retirement outcomes are more reliant on investment returns. The risk is also apparent in all portfolios which are experiencing capital changes via either contributions or distributions.

Basu and Drew (2009a) introduced the notion of the 'portfolio size effect' to the literature. They found that the investment return attributed to DC plans towards the end of the accumulation (and early decumulation) period is the main driver of terminal wealth in a DC plan. In practical terms, the largest losses (and gains) are made when the largest amount of retirement savings is at risk. The intersection between the portfolio size effect and sequencing risk leads to some interesting insights: see figure 6.

Returning to the hypothetical member, starting their working life in 2012 at age 25 and experiencing the identical return path that occurred from 1972 to 2011, figure 6 illustrates each contribution's growth through time from the 1972–2011 return path (identical to figure 4, a final accumulated balance at age 65 of $4.0 million, with contributions of $373,325). Recall that the simplifying assumption was made that there are 41 annual contributions made by the member from 2013 to 2052 (final contribution does not experience a return) . The teal circle in figure 6 indicates the point at which the cumulative contributions (black line) are half (or 50 per cent) of the total portfolio size. In the case of the hypothetical member this occurs at 37 years of age.

The analysis provides further insight into the working definition of sequencing risk — *the worst returns in their worst order*. Using the 73 historical returns paths as a guide (1900–1939, 1901–1940 … 1972–2011) different return paths are applied to the 25-year-old member commencing in thier DC plan in 2012. Figure 7 illustrates every 40-year path's cumulative contribution divided by accumulated retirement savings (or total portfolio size to date) across the entire accumulation period. It is important to note the significance of the colour coding in figure 7. The gold section represents all 40-year paths, which end from 1939 to 1970 (n = 32) while the teal section represents all 40-year paths, which end from 1971 to 2011 (n = 41). This colour coding is consistent throughout this study.[14]

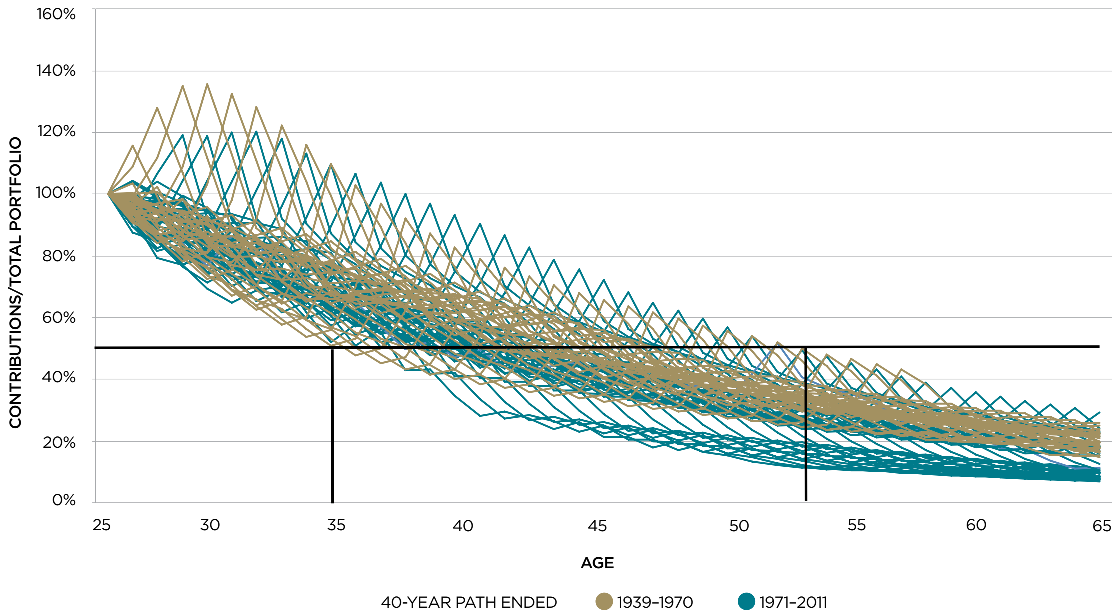
Figure 6: The default strategy's growth through time for the 40-year accumulation period from 1972 to 2011 — each colour represents a different contribution path through time



14. Some of the paths in figure 7 illustrate contributions totalling greater than 100 per cent of the portfolio. This has occurred due to paths experiencing large or multiple negative returns in the early years of accumulation (such as those just prior to the 1974 crash) and thus their investment earnings are negative and have reduced total portfolio sizes below that of the cumulated contributions to date.

Figure 7 highlights the point at which the 50 per cent contribution-to-total portfolio size point is reached and, as expected, this is dependent upon the order of the returns. For all of the 40-year accumulation paths from 1900 to 2011 (as applied to the hypothetical member), the range of outcomes is between 34 and 54 years of age (the 9th and 29th years of accumulation, respectively). It can be seen that, beyond this point, the acceleration towards investment returns accounts for an increasingly larger proportion of the portfolio balance. While acknowledging the distribution of particular outcomes, one important point to note from figure 7 is that in the final years of the accumulation phase (say, the last 10 from age 56), a rule of thumb can be applied such that contributions only account for about one-fifth (or 20 per cent) of the total DC plan size.[15] The findings suggest that there is something similar to the Pareto principle[16] ('the vital few and trivial many') at play with sequencing risk; that is, late in the accumulation phase around 80 per cent of the member's final balance is attributable to returns, and 20 per cent to contributions.[17] This provides further nuance to our understanding of sequencing risk, *the worst* returns in their worst order. The finding suggests that even muted levels of bad volatility, occurring at the worst time, can have a significant impact on members' retirement savings. Indeed, it is not necessarily the magnitude of the negative return that matters, but its timing.

Figure 7: Total cumulative contributions as a percentage of total portfolio balance for all 40-year accumulation paths from 1900 to 2011 using the default strategy's annual returns (n=73)



15. This rule of thumb is supported by the inflation-adjusted analysis presented in Appendix 3, where it is a 40 per cent (contributions), 60 per cent (returns) general rule.

16. The term 'the Pareto principle' and the associated quote 'the vital few and the trivial many' has been attributed to Joseph M. Juran (1904–2008) based on the work of Vilfredo Pareto, for a discussion see: www.juran.com/index.html

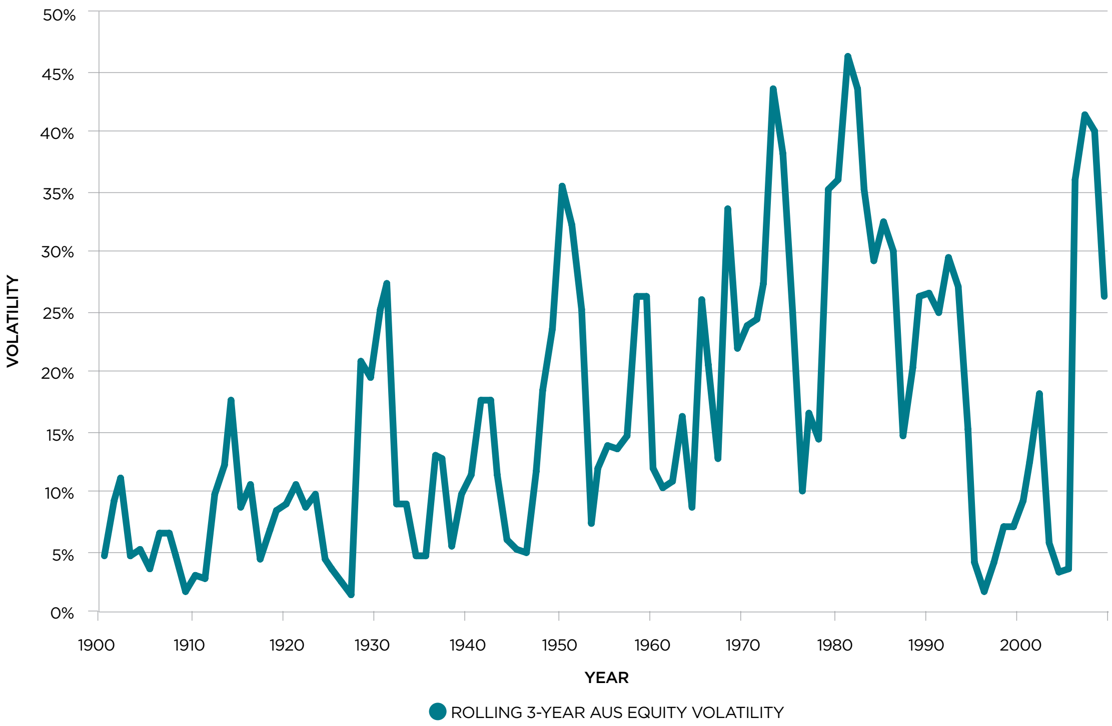
17. The mean (contribution/portfolio balance) 10 years from retirement for all 40-year accumulation paths is 21 per cent while the minimum and maximum are eight per cent and 44 per cent, respectively.

3. WHERE IS SEQUENCING RISK GOING?

The case has been made that sequencing risk becomes more acute closer to retirement when the portfolio size grows exponentially with returns dwarfing contributions. Now the volatility of a DC plan's balance in percentage terms needs to be brought to the fore. In dollar terms, volatility on a small portfolio balance does not impact the dollar value as severely as the same volatility on a large portfolio balance. Using rolling three-year volatility from Australian equities as a guide, it can be seen that the volatility of returns has been increasing over the past 112 years. Intuitively, this makes sense as a number of events that have caused major disruptions to financial markets have occured during the past quarter century: from the 1987 stock market crash through to the global financial crisis. In this section, the impact of a higher standard deviation of returns in the later years of the working life is explored, finding that this results in a higher variation in retirement wealth outcomes for DC plan members.

The rolling volatility results shown in figure 8 confirm that the standard deviation of returns for Australian equities has been on the rise over the past century. To illustrate the distributional characteristics of the data from 1900 to 2011 for the default strategy, a histogram can be constructed. However, a standard histogram provides a limited insight into the time-varying characteristics of the return volatility. Figure 9 depicts a histogram of the annual returns from the default strategy (66/26/8 stocks/bonds/bills allocation) for the period 1900–2011. Note that the colour coding used in this histogram is the same as that used in the previous section; the gold represents returns which affect the 40-year accumulation paths ending 1939–1970, while the teal represents the returns which affect the 40-year accumulation paths ending 1971–2011. The blue is included in this diagram as there are some return paths which overlap into both subsets.

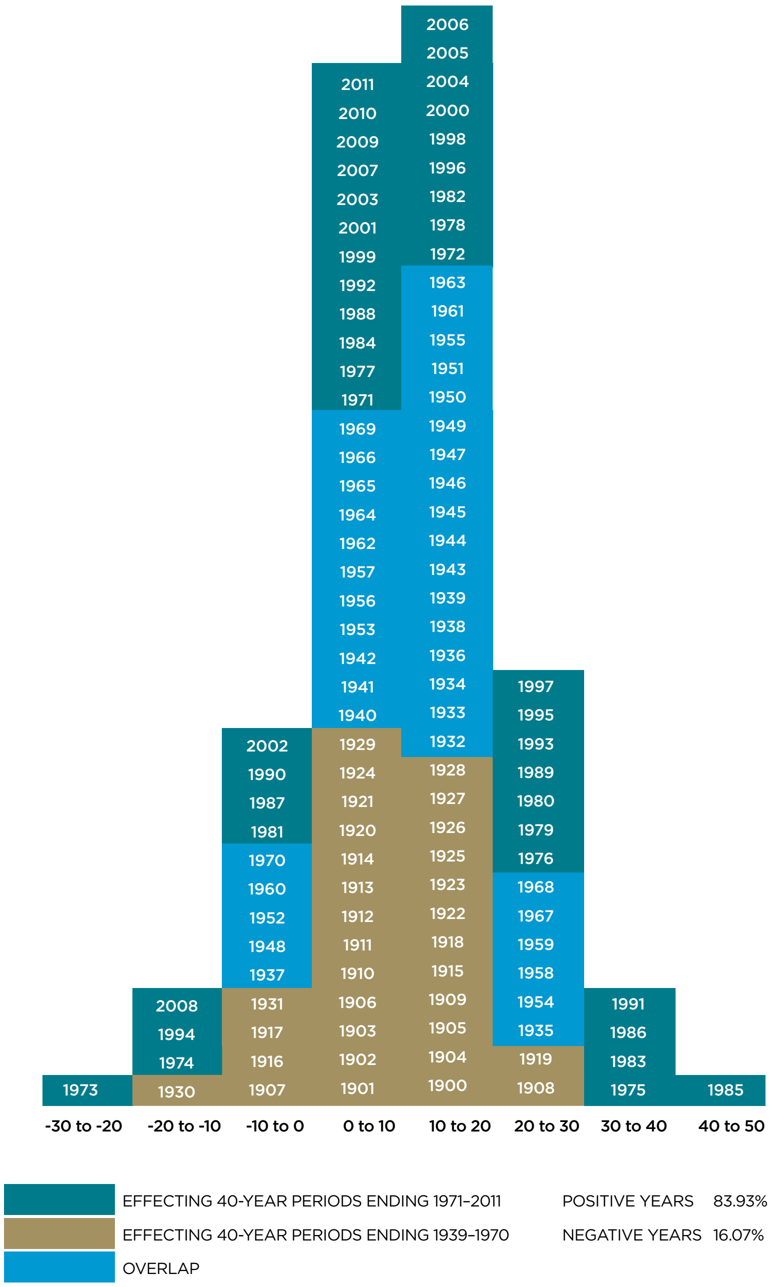
Figure 8: Rolling three-year Australian equity volatility from 1900 to 2011



The histogram in figure 9 shows that the returns from the latter part of the sample period are more dispersed than those encountered earlier in the sample.[18] This particularly is evident in the tails of the distribution, such as the -30 to -20 per cent bucket (1973), the +30 to +40 per cent bucket (1975, 1983, 1986 and 1991) and the +40 to +50 per cent bucket (1985).

With the confirmation that historical volatility is increasing through time, the potential impact this may have on the hypothetical DC plan member can be seen. Figure 10 shows every historical 40-year return path that is available from the sample (with the first being 1900–1939 and the last being 1972–2011). These respective sequences or paths of returns are applied to the hypothetical member commencing in the DC plan in 2012.

Figure 9: Histogram of the default strategy's annual returns (1900–2011)



18. It is important to note that the distribution of real returns has greater negative skewness and fatter tails, making the problem of sequencing risk potentially more pronounced (see appendix 3).

The volatility of returns, combined with their historical order, is a driving force for the distribution of retirement outcomes for the hypothetical member. The results show a clear increase in the range of possible outcomes over time. If the hypothetical member were to experience 40-year accumulation paths similar to that from 1939 to 1970 (gold), this would result in a distribution of final account balances of between $1.9 million and $3.2 million — a comparably narrow range of around $1.3 million. However, if the hypothetical member were to experience paths of returns similar to that for periods ending 1971–2011 (teal) in the future, the member would have a much wider distribution of retirement outcomes, albeit with a larger average balance. These outcomes range from $1.4 million (using the return path concluding in 1974) to a maximum of $6.7 million (the return path concluding in 2000) — a range of around $5.3 million.

The interplay between the distributional characteristics of the returns and the sequence in which they are experienced are important considerations for DC plan members. However, it would be unrealistic to conclude that the distributional characteristics of the final account balances presented in figure 10 are driven purely by sequencing risk. Some of the historical paths used in the analysis have superior average returns and thus represent a better path in general. To quantify the effect that sequencing risk has on the individual paths, their returns using a form of heat map are considered. Figure 11 presents the return paths experienced by each of the 40-year accumulation paths. The colours in the heat map are coded as follows:

> annual returns below the long-term average annual return are light blue;

> annual returns above the long-term average annual return are teal; and

> extreme returns are red (negative) and gold (positive) (extreme returns are classified as being beyond two standard deviations from the average return).

Figure 10: Every 40-year accumulation path from 1900 to 2011 using the default strategy's annual returns (n=73)

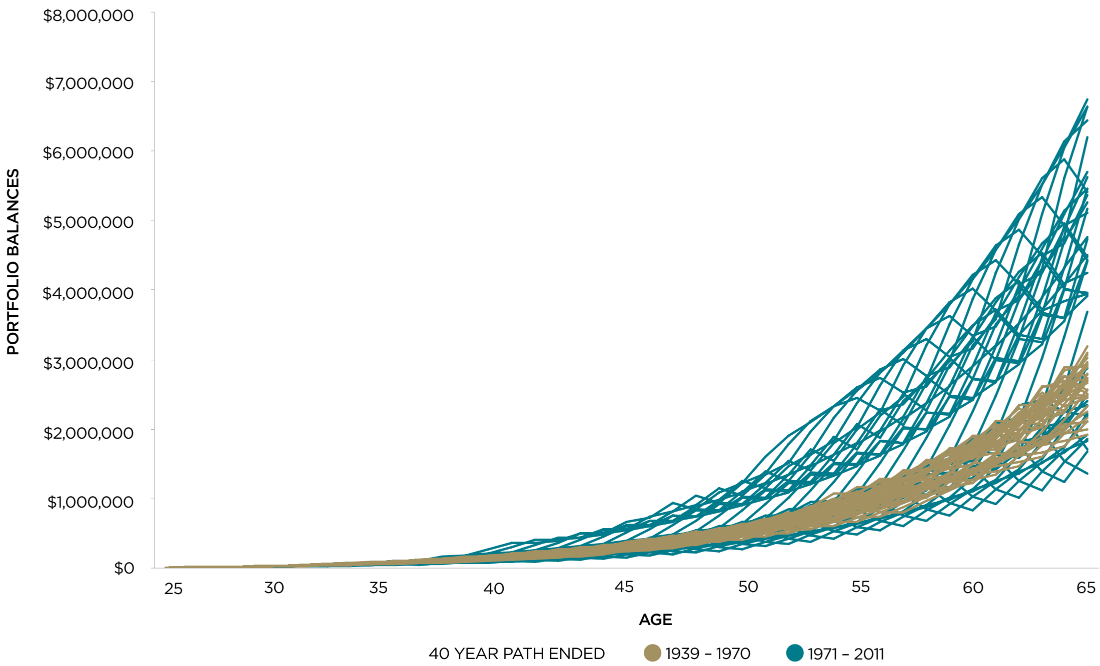
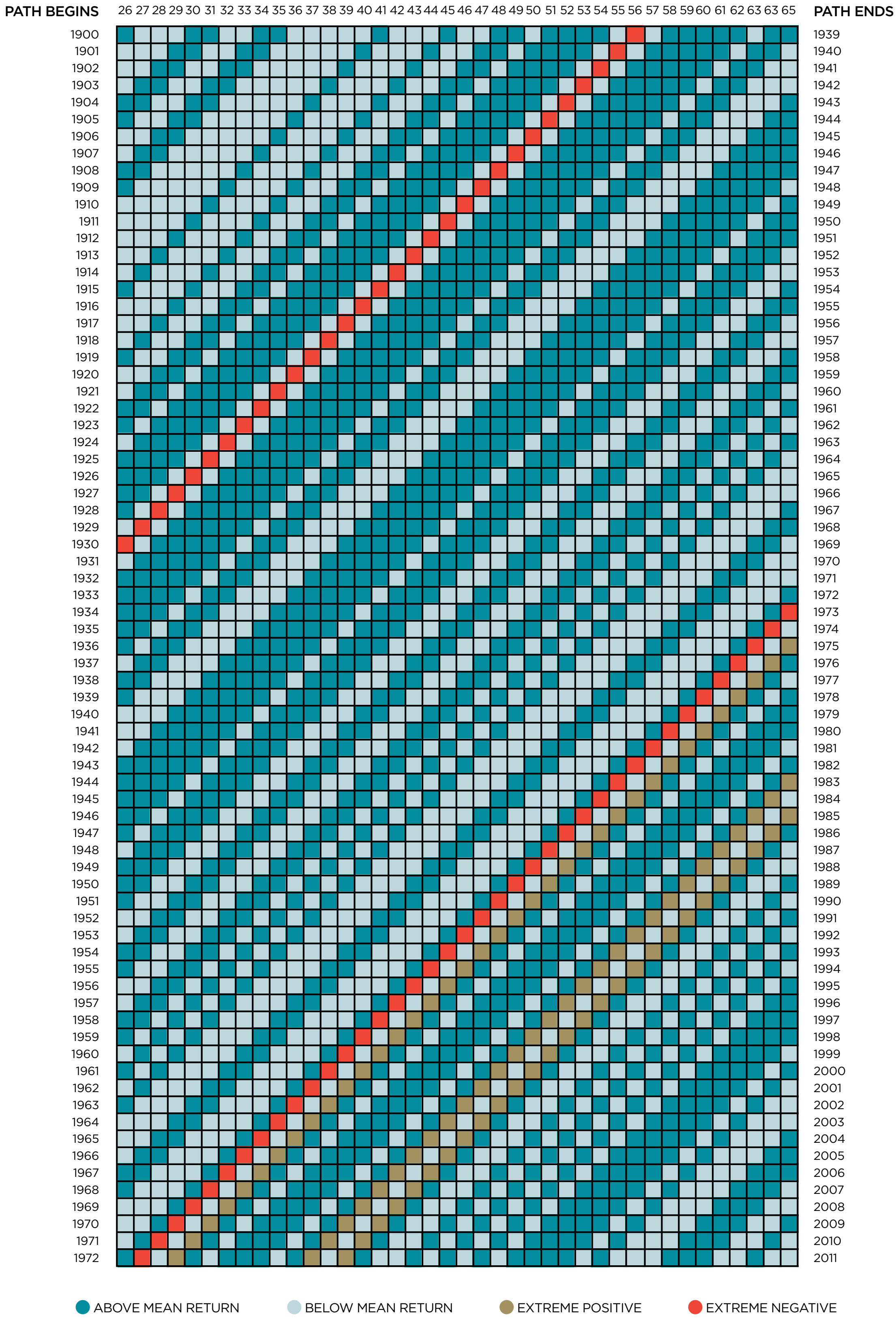


Figure 11: Heat map of the default strategy's annual returns for every 40-year accumulation path from 1900 to 2011 (n=73)



Perhaps the most striking feature of the heat map is just how different the order of the returns has been throughout history. Examining an extract from figure 11, figure 12 illustrates the best (path ending 2000) and worst (path ending 1974) paths.

Figure 12: Best and worst 40-year accumulation paths (figure 11 extract)

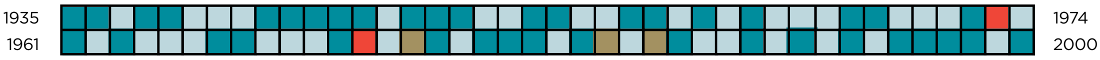
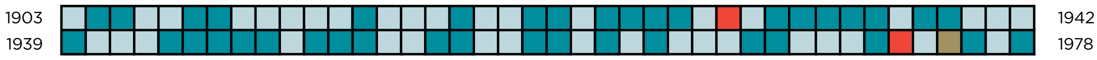


Figure 12 shows a large group of positive returns (gold) for the 2000 path, the best performing path ($6.7 million). The large negative (red) returns that occurred late in the path ending 1974 illustrate why this is the worst performing path ($1.4 million). The best performing path also faced similar large negative returns; however, this was experienced much earlier in the accumulation path.

Looking at another two paths from figure 11, figure 13 illustrates two paths which had similar outcomes — paths ending 1942 and 1978.

Figure 13: 1942 and 1978 40-year accumulation paths (figure 11 extract)



The two paths ending 1942 and 1978 in figure 13, both had a final portfolio balance of $1.9 million (with a difference of only $506). These similar results occurred despite the fact that there was a markedly different order of the returns during the final decade. However, if one looks at each path's arithmetic and geometric returns (listed in table 4), some interesting results are found.

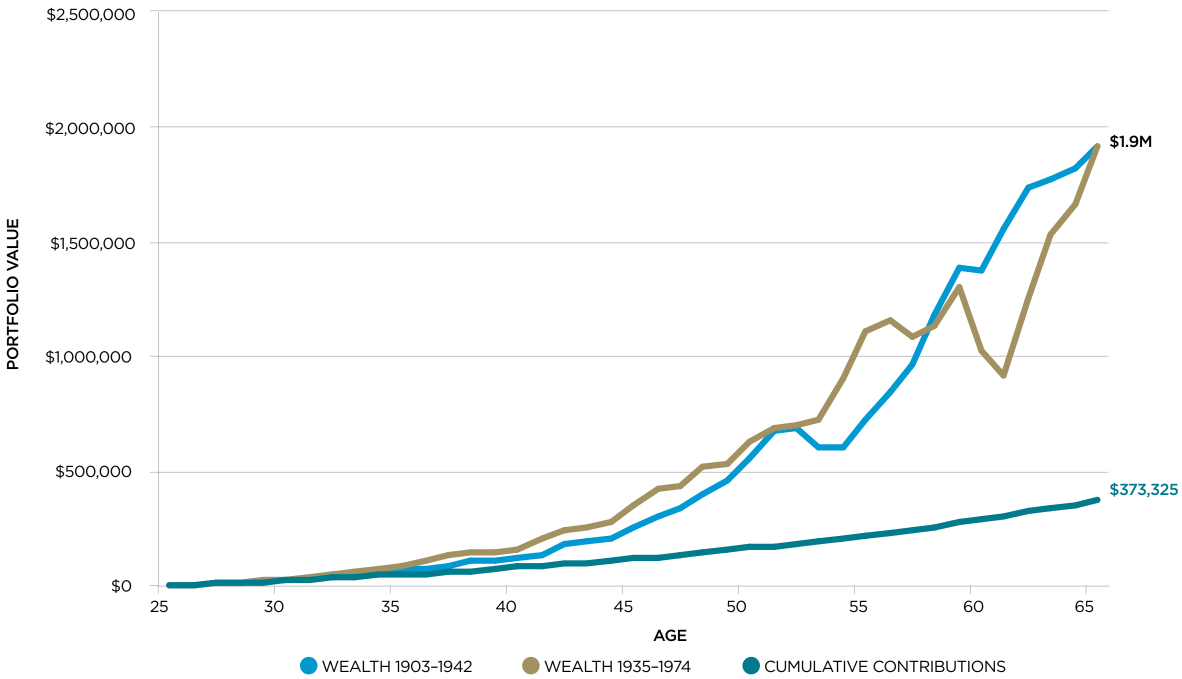
Table 4: Arithmetic and geometric returns for 40-year accumulation paths from figure 13 (40-year accumulation paths ending 1942 and 1978)

	1942	1978
Arithmetic return per annum	8.69%	9.40%
Geometric return per annum	8.36%	8.69%
Terminal wealth	**$1.9m**	**$1.9m**

While the annual rates of return experienced by each path are quite different, the final balances (that is, the total retirement nest egg) are essentially the same. The 40-year accumulation path ending 1978 has an arithmetic (geometric) return 71 (33) basis points per annum or 8.17 (3.95) per cent per annum greater than the 1942 path, yet the terminal wealth outcome is virtually identical (the 1942 path actually beats the 1978 final account balance by around $500). Sequencing risk is the key reason the accumulation path ending in 1978 is reduces wealth so severely in the final years of accumulation. Figure 14 illustrates the two (1942 and 1978) wealth paths over their 40-years of accumulation. It is important to note that at age 55, these two paths have an accumulation of $730,000 and $1.1 million for 1942 and 1978 respectively, yet they both end up with total accumulated wealth of $1.9 million.

Figure 14 helps illustrate the final years of accumulation for both paths and shows the large negative return experienced by the 1978 path just six years from retirement (which represents 1973 return, followed by a large below mean return in 1974), severely affecting the portfolio. Even with the positive returns at the end of the accumulation period, it is difficult to recuperate from these losses and there is insufficient time to return the wealth trajectory to the level before these negative returns.

Figure 14: Two 40-year default strategy accumulation paths for years ending 1942 and 1978



4. HOW TO CONSIDER THE 'KNOWN UNKNOWNS' OF SEQUENCING RISK

In a now infamous US Department of Defense briefing in February 2002, the then Secretary of Defense, Donald Rumsfeld, stated 'there are known knowns. These are things we know that we know. There are known unknowns. That is to say, there are things that we know we don't know. But there are also unknown unknowns. There are things we don't know we don't know'. It seems that in the sequencing risk debate there are some 'known unknowns'; that is, there is over a century of empirical return data to sample from, but given the 40-year accumulation horizon in a typical DC plan (and much longer if the full decumulation phase is included), there are relatively few paths (73) to consider. Many different outcomes are possible for the order of returns. Hence, DC plan members face a 'known unknown'.

A further complication is that in order to appreciate fully the impact of sequencing risk, many of the input variables need to be kept constant so the focus can be on the interplay between the final accumulated balance in a DC plan and the order of returns. The literature provides some excellent examples of various return-generating methodologies based on stochastic bootstrap and factor-based approaches.[19] However, the challenge for this study is to generate return paths from these approaches which may not hold all other variables constant to measure sequencing risk (that is, these generated paths may not have the same mean, standard deviation, skewness and excess kurtosis), making comparability difficult. Hence, the challenge is to find a methodological approach that holds these known measures of risk constant to evaluate sequencing risk.[20]

The bootstrap approach is used to 'shuffle' the returns, with the defining feature being the resampling without replacement. Each 40-year period is taken and the returns shuffled within that period a total of 10,000 times. (This results in 73 historical return paths x 40 annual returns x 10,000 times, a total of 29.2 million return points. Then 730,000 different final balances were generated for the hypothetical member at age 65 and these figures are presented in figure 15.) In figure 4, one actual return path (1974–2011) was taken and one reshuffle of the path (reverse ordered) was made. Here, 10,000 reshuffles are undertaken to quantify the impact of sequencing risk. The percentiles of the distribution are taken to create a heat map illustrated in figure 15.[21]

Figure 15 further highlights the impact that the order of returns potentially has on terminal wealth.[22] The horizontal axis represents the year in which the 40-year accumulation path ends while the vertical axis represents the final portfolio balances of that particular path where the returns are reshuffled 10,000 times and applied to the hypothetical DC plan member aged 25 years. The black line in figure 15 represents the final balance the member would receive if the historical path were repeated over the 40-year accumulation phase.[23] In summary, this line represents the actual final portfolio balances which the hypothetical DC plan member would receive if the path of returns over the 40-year period selected were to occur. It is interesting to track this line closely through the different periods. The line tracks into the 7th percentile in the path ending 1974 and enters the 92nd percentile in the path ending 2000. The respective percentile values, actual portfolio values and actual portfolio value

19. Bootstrap, Monte Carlo distributions and Economics Scenario Generators (ESGs) are some of the methods commonly found in the literature. See, for example, Blake, Cairns and Kevin (2001, 2003); Frank, Mitchell and Blanchett (2010, 2011); Basu and Drew (2009a); Basu, Byrne and Drew (2011); Dolvin, Templeton and Rieber (2010); Antolin, Payet and Yermo (2010); Mowbray (2010); and Scheuenstuhl et al. (2010). The bootstrap approaches presented in the literature create multiple paths by resampling with replacement. Such studies have differing moments of distribution and thus conclusions cannot be drawn about the unique impact of sequencing risk. A similar concern can be levelled at Monte Carlo simulations. ESGs draw on economic data and correlations with asset returns through time to produce scenarios which, by their nature, do not hold the four moments of the distribution constant. In no way are these respective approaches being rejected. They play an important role in the DC debate (with various papers by the authors, see Basu and Drew (2009a) employing a range of these techniques); however, for the research questions posed in this study, comparability of paths is key.

20. To quantify the impact of sequencing risk, the assumptions to produce the wealth outcomes and the paths' respective four moments of the distribution need to be held constant. Frank and Blanchett (2010) simulate sequencing risk by 'equalising' the mean and standard deviation of a Monte Carlo distribution. While this is an interesting approach, the motivation of this paper is to show sequencing risk when all assumptions and when all four moments are held constant. Dichev (2007) uses a simple, yet intuitive, technique to produce his results via a bootstrap method, which does not use resampling. The approach here, which simply shuffles the return series, all four moments to be retained constant, allowing sequencing risk to be quantified.

21. It is important to note that even shuffling these 40-year paths 10,000 times does not capture every possible combination. The total number of combinations which can be found is 8.159×10^{47}. This number is derived as the probability for the first number is 1 in 40, the second return is 1 in 39 and so on. It is known as a factorial of 40 (40x39x38x...x1). The maximum and minimums plotted in figure 15 do not represent the global maximum and minimum which can be found in the total number of combinations but rather the local extremes found in the 10,000 resampled paths.

22. Basu and Drew (2009a, 2010); and Antolin, Payet and Yermo (2010) are followed by reporting the retirement wealth ratio (RWR), which compares the terminal DC plan member's final year earnings to the terminal wealth of the plan, as a benchmark to evaluate different outcomes. Other objective functions may include the use of annuity equivalent values (AEVs). All of these measures attempt to provide some anchor regarding terminal wealth as a multiple of final salary (RWR) or the potential income stream that may be derived from terminal wealth.

23. For instance, 1939 represents a final balance for the hypothetical DC plan member aged 65 in 2052 of $2.3 million, a full list of final balances (and distributions) is provided in appendices 1 and 2.

percentiles for these paths are presented in table 5. The most recent 40-year accumulation path (1972–2011) is indicated in table 5.

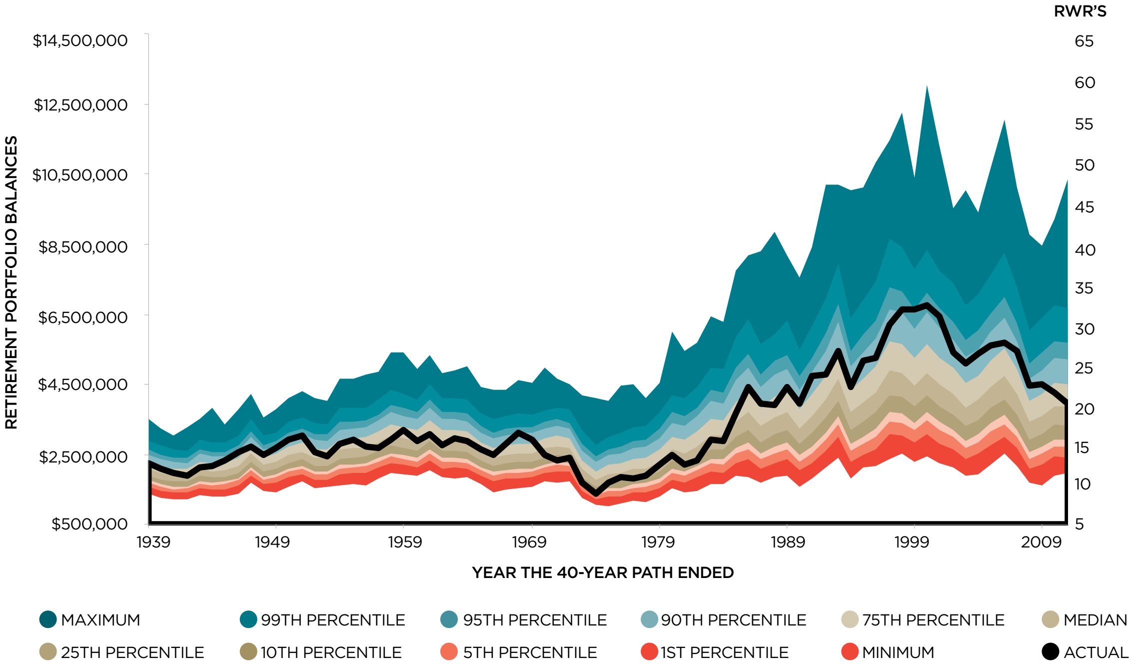
It can be seen that a DC plan member experiencing a path similar to 1974 would have had the worst outcome over the past century. The 1974 crash saw markets fall over a quarter of their value and the default strategy used in this study experienced a -12 per cent return for the year. This was coupled with the previous year (1973) recording a -22 per cent fall, quite literally the worst returns at their worst time.

Returning to table 5, the actual return for the 1935–1974 path landed in the 7th percentile of the simulation, while the 1961–2000 path landed in the 92nd percentile. These two extremes highlight that the extreme outcomes shown in figure 15 may not be completely unrealistic, and could occur in the future. The distribution of outcomes in figure 15 gives a range of possibilities that could play out in the future.[24]

Restricting the range of outcomes to the inter-quartile ranges, 34 out of the 73 actual 40-year paths lie outside their respective quartile ranges.[26] This again supports the view that the distributions of outcomes in figure 15 are not unrealistic, with almost half of the 40-year paths resting beyond their respective inter-quartile ranges.

It is a sobering thought that while the global financial crisis has raised significant debate about its impact on DC plans, the 40-year periods ending 2008, 2009 and 2010 were challenging but did not produce the worst order of returns in recent financial history. However, one caveat to this is that while the hypothetical DC plan member does not deviate from contributing nine per cent of wage and salary to superannuation annually, this is not the reality for most DC plan members. They tend to back-load their contributions (say, when the mortgage is paid off and dependents have left home), making the sequencing risk profile for uneven contributions even more dramatic. While this modeling is left to future research, the importance of the timing of these large contributions is acknowledged.

Figure 15: The default strategy's annual returns are used to determine every 40-year accumulation path from 1900 to 2011. (These were reshuffled via a bootstrap method 10,000 times each to simulate 10,000 final portfolio balances; assumptions about wealth creation are illustrated in table 1.)



24. One of the interesting results from the confirmatory analysis using real returns was the percentile that the actual paths experienced ranged from below the 5th percentile to above the 95th percentile (appendix 3).

25. See appendices 1 and 2 for final account balances (and percentiles) presented in figure 15.

Table 5: Actual final account balances with percentiles of the distributions for the worst 40-year accumulation path, best 40-year accumulation path and the most recent 40-year accumulation path using the default strategy's annual returns and the assumptions from table 1

	1935–1974 (WORST)	1961–2000 (BEST)	1972–2011 (MOST RECENT)
Minimum	$1,060,183	$2,445,751	$1,977,212
1st percentile	$1,221,898	$3,094,457	$2,424,586
5th percentile	$1,336,596	$3,468,941	$2,730,901
10th percentile	$1,416,253	$3,703,808	$2,935,151
25th percentile	$1,573,718	$4,182,929	$3,328,848
50th percentile	$1,778,886	$4,838,148	$3,865,317
75th percentile	$2,027,063	$5,654,434	$4,521,889
90th percentile	$2,283,077	$6,574,957	$5,230,972
95th percentile	$2,452,383	$7,126,916	$5,682,110
99th percentile	$2,768,281	$8,349,384	$6,683,261
Maximum	$4,117,753	$13,037,075	$10,363,284
Actual	$1,365,407	$6,745,033	$3,951,186
Actual percentile	6.58%	91.83%	53.93%

5. HOW TO MANAGE SEQUENCING RISK

The problem of sequencing risk arises because of the regular contributions going into the portfolio at every period of the investment horizon. Put simply, if the member were to make one single lump sum contribution at the beginning of the horizon, the accumulation at the end of the investment horizon would be dependent on the returns of every period but not on the sequence in which they occur. In this case, the sequence of returns would be irrelevant to the investor. On the other hand, regular contributions (or distributions) into the member account make the sequence of returns influential in determining final wealth outcomes. While sequence of returns would still be relevant with equal dollar contributions every period, the fact that the contributions are unequal over time make the risk more acute. As the contributions generally increase over the working life of individuals, it leads to their being better (worse) off when experiencing the best (worst) returns in the years leading up to retirement and the worst (best) ones early in their career.

Having established both the existence of sequencing risk confronted by all superannuation fund members and quantifying its impact on their retirement portfolio value, the logical question that follows is: how should it be managed? The age-old cure of diversification between different asset classes does not directly address this problem.[26] To devise strategies to manage sequencing risk, one needs to acknowledge the source of this risk as indicated above.

It is the periodic contributions by members that produce sequencing risk. Moreover, inequality in lifetime contributions turns this risk into an 800-pound gorilla as members approach retirement. Any strategy claiming to reduce sequencing risk needs to confront this inequality in contributions over the investment horizon.

Two ways are suggested to spread contributions more evenly over the working life of the investors thereby reducing sequencing risk. First, the contribution rates could be set higher initially and gradually brought down as one approaches retirement. This would make contribution sizes increase (decrease) in the earlier (later) part of the horizon thereby directly addressing the unequal contribution problem. By setting a higher contribution rate when incomes are typically lower and lower contribution rates when incomes are generally higher, the gap between contribution sizes at different lifecycle stages could be minimised. This could be achieved by setting the highest and the lowest contributions rates around an average lifetime contribution rate. (This may be equal to the current or future mandatory superannuation guarantee provisions.) The obvious difficulty in implementing such a policy would be the reluctance of investors to put more money into superannuation when they are younger, leaving less income for consumption.

The alternative to setting unequal contribution rates would be to adjust asset allocation over the working life to achieve higher portfolio exposure to growth assets in the early years than occurs with existing exposure levels. This would imply embracing a whole-of-life approach to DC plan design that invests mostly in equities in the initial and middle years but switches towards less volatile assets when approaching retirement. This is in contrast to the target risk or fixed allocation strategy adopted by most Australian superannuation funds in which the same proportion of equities (and other assets) exists for workers joining the workforce as those that are leaving it (Towers Watson 2012). A differential allocation across the investor's working life is suggested that can be built around an average dollar-weighted allocation, which is similar to the default asset allocation of the average superannuation fund. The investor would push up equity exposure to near 100 per cent at the beginning of their career but reduce it very aggressively in the years approaching retirement.[27] This strategy would allow for robust portfolio growth in the early years but cushion the impact of stock market downturns in the final years.[28]

26. This is not to deny that a diversified portfolio may dampen the amount of sequencing risk in a portfolio, which consists of only equities. There is a very important debate emerging around this issue, see Leibowitz and Bova (2009).

27. A higher than 100 per cent exposure to equities in the early years can also be achieved using call options on equity indices. This would allow for reductions in the equity exposure of the portfolio over time at a much faster rate than would otherwise occur (Ayres and Nalebuff 2010). Investors may also consider a dynamic approach to asset allocation informed by their retirement outcome objectives (Basu, Bryne and Drew 2011).

28. While the discussion is specifically focused on the core elements of sequencing risk, it is noted that a range of other practical strategies may be available to members. In addition to changes to the asset allocation through different life stages, other strategies may include: additional contributions (although it is noted that the issue of back-loading voluntary contributions in the years immediately preceding retirement may actually exacerbate sequencing risk); tax incentives for making contributions earlier in the accumulation phase; the potential to delay retirement (in reality, there may be some flexibility as to the retirement date); and tail insurance (downside risk overlays). These are all part of the broader debate.

CONCLUSION

Conventional wisdom suggests that, given a certain level of contributions, retirement wealth depends on the number of good and bad return periods experienced over a lifetime and the magnitude of those good and bad returns. In this paper, it has been demonstrated that the retirement wealth of long-term investors with multiple cash flows is not only affected by the frequency and magnitude of good and bad returns, but also by the sequence in which those returns occur. In short, the potential for DC plan members to experience the *worst returns in their worst order* should be seen as an important risk. Multi-period investors with identical average returns and volatilities over their lifetime will confront vastly different retirement wealth outcomes if the periodic returns are experienced in different orders or sequences.

Unfortunately, the sequence of market returns is beyond the control of investors, posing a real risk that returns will not follow their preferred sequence and therefore have adverse effects on their retirement nest egg. So, who owns the risk? In a DC-oriented system like that in Australia, it seems that sequencing risk adds to the range of other important risks (such as inflation, market, liquidity and longevity) faced by plan members.[29] Sequencing risk has a pervasive effect on the sustainability of retirement income for DC plan members. The risk particularly is acute around the period in which retirement savings are at their zenith.

In the foreword reference was made to the wisdom of Samuel Taylor Coleridge who described poetry as 'the best words in their best order'. The works of Coleridge and his contemporaries (Blake, Byron, Shelley, Keats and Wordsworth) saw the emergence of Romanticism in the late 18thcentury, a literary movement that placed new emphasis on individual uniqueness.[30] The findings in this paper suggest that there are two possible ways of diluting the impact of sequencing risk: adopting a strategy that either reduces the portfolio size effect (by spreading dollar-weighted allocations more evenly over one's investment life) or taking a whole-of-life approach to DC plan design. Investment markets do not afford the luxury of rearranging and reordering returns to find the perfect sequence. However, there is an opportunity to enhance retirement outcomes in DC plans through better understanding the individual uniqueness of plan members.[31]

The omnipresent nature of sequencing risk demands new thinking and approaches to managing the problem of 'the worst returns in their worst order'. Perhaps like the poets from the Romantic era, a new movement in retirement saving framed around the individual uniqueness of DC plan members is needed, shifting from a debate where success is framed around time-weighted metrics (risk, reward and peers) to the things that matter for investors — dollar-weighted returns.

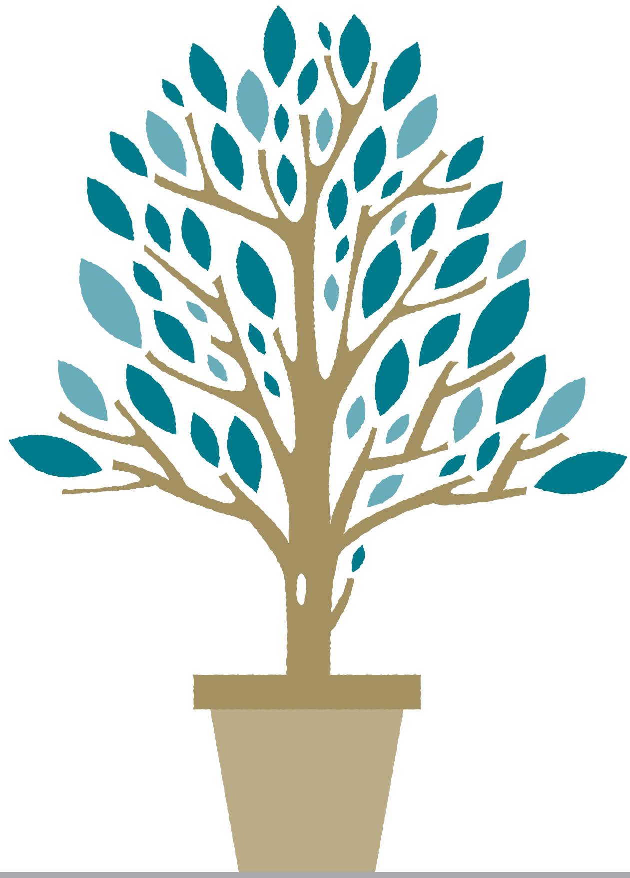
To improve retirement outcomes for members, there is a need to ensure that the conversation about the management of sequencing risk, which often occurs during the critical retirement conversion phase, is brought forward to be at the heart of DC plan design and governance. This involves considering the impact of sequencing risk during an investor's pre- and early-retirement phase (say, the final 15 years of the accumulation period and the first decade of the distribution phase). Particularly during this critical conversion phase, many investors are unaware that it is not the average return of their investments, but the realised sequence of those returns, that can largely determine the sustainability of their retirement income. With increasing numbers of baby boomers entering this phase, the sequence of returns risk is a current and significant challenge.

29. The challenges that sequencing risk may pose for public policy are formally acknowledged, particularly for the provision of the public pension. Potentially, sequencing risk fragments outcomes for members of DC plans and, as a result, this is problematic in terms of policy outcomes. It is submitted that this line of investigation is important and future researchers are encouraged to consider sequencing risk more formally through the lens of public finance. The importance of sequencing risk for self-managed superannuation funds (SMSFs) is also noted and this issue is left for future researchers.

30. For an overview of this period in literary history see the website maintained by Professor Robert Schwartz at: https://www.mtholyoke.edu/courses/rschwart/hist255/index.html and the BBC's online resource: www.bbc.co.uk/arts/romantics/

31. Potentially, sequencing risk is not only borne by an individual. The problem for public policy arises when it is not just one individual who suffers a large loss on their retirement savings, but an entire cohort that endures the same loss. This is a realistic scenario with around 80 per cent of all Australians being enrolled in the default option and thus experiencing similar return paths with only minor differences between fund default strategies (Towers Watson 2012).

REFERENCES
and appendices



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APPENDICES

Appendix 1

Table A1: Actual final account balances along with mean, median, standard deviation and interquartile range for the final portfolio balances from figure 15.

RETIREMENT YEAR	ACTUAL	MEAN	MEDIAN	STANDARD DEVIATION	INTERQUARTILE RANGE
1939	$2,254,561	$2,113,273	$2,087,697	$290,253	$389,384
1940	$2,106,244	$1,979,401	$1,952,584	$279,014	$374,527
1941	$1,988,646	$1,921,716	$1,893,125	$270,545	$364,094
1942	$1,912,914	$1,913,458	$1,888,584	$263,483	$356,999
1943	$2,117,844	$2,111,708	$2,082,327	$297,507	$397,483
1944	$2,158,523	$2,052,776	$2,024,008	$292,028	$393,801
1945	$2,322,076	$2,059,661	$2,032,699	$287,245	$382,897
1946	$2,565,106	$2,208,271	$2,177,477	$312,945	$424,395
1947	$2,737,684	$2,553,221	$2,516,230	$344,582	$461,369
1948	$2,472,006	$2,222,161	$2,191,558	$302,354	$403,598
1949	$2,684,972	$2,311,842	$2,282,826	$314,067	$424,786
1950	$2,911,902	$2,514,374	$2,482,831	$343,250	$460,366
1951	$3,026,912	$2,608,966	$2,569,532	$352,133	$474,159
1952	$2,557,093	$2,432,172	$2,399,244	$354,556	$473,905
1953	$2,455,178	$2,429,412	$2,396,037	$348,679	$470,924
1954	$2,797,518	$2,680,340	$2,635,648	$404,250	$536,983
1955	$2,938,755	$2,707,861	$2,665,877	$402,390	$544,860
1956	$2,725,540	$2,738,293	$2,699,814	$404,501	$539,887
1957	$2,687,332	$2,902,485	$2,856,789	$417,409	$552,710
1958	$2,921,886	$3,089,505	$3,039,938	$454,966	$606,436
1959	$3,189,883	$3,014,345	$2,967,587	$437,116	$582,619
1960	$2,896,965	$2,929,841	$2,884,227	$429,935	$584,309
1961	$3,061,133	$3,199,575	$3,147,037	$467,002	$617,854
1962	$2,775,025	$2,915,790	$2,868,665	$436,471	$584,936
1963	$2,964,702	$2,936,213	$2,896,585	$434,216	$582,161
1964	$2,879,472	$2,883,308	$2,842,458	$426,660	$568,787
1965	$2,657,903	$2,608,493	$2,569,008	$391,008	$517,213
1966	$2,467,391	$2,453,002	$2,409,882	$376,654	$499,080
1967	$2,790,946	$2,525,067	$2,483,095	$385,345	$515,853
1968	$3,099,550	$2,562,871	$2,520,031	$399,302	$526,109
1969	$2,937,397	$2,575,739	$2,536,151	$392,761	$527,030
1970	$2,505,565	$2,703,758	$2,665,929	$394,348	$527,827
1971	$2,344,418	$2,781,385	$2,739,748	$397,232	$533,929
1972	$2,402,492	$2,723,568	$2,683,892	$387,024	$516,229
1973	$1,702,719	$2,125,635	$2,079,800	$370,854	$488,676
1974	$1,365,407	$1,821,738	$1,778,896	$341,777	$453,344

Appendix 1 continued

Table A1: Actual final account balances along with mean, median, standard deviation and interquartile range for the final portfolio balances from figure 15.

RETIREMENT YEAR	ACTUAL	MEAN	MEDIAN	STANDARD DEVIATION	INTERQUARTILE RANGE
1975	$1,684,724	$1,965,612	$1,917,518	$373,950	$496,179
1976	$1,856,321	$2,015,490	$1,968,591	$395,861	$519,301
1977	$1,831,910	$2,122,200	$2,073,001	$410,064	$537,747
1978	$1,912,408	$2,155,849	$2,107,809	$409,411	$546,169
1979	$2,216,658	$2,363,151	$2,303,843	$461,338	$602,412
1980	$2,498,472	$2,702,380	$2,631,773	$532,772	$693,371
1981	$2,197,830	$2,606,769	$2,532,474	$520,710	$680,186
1982	$2,324,536	$2,816,167	$2,738,589	$562,417	$742,140
1983	$2,926,721	$3,135,525	$3,046,556	$647,115	$853,730
1984	$2,877,770	$3,102,739	$3,021,500	$635,537	$834,689
1985	$3,690,741	$3,562,499	$3,445,726	$771,700	$985,462
1986	$4,415,392	$3,824,436	$3,706,042	$853,940	$1,089,755
1987	$3,957,557	$3,407,855	$3,303,653	$761,919	$970,869
1988	$3,920,999	$3,661,888	$3,544,493	$810,101	$1,063,693
1989	$4,435,775	$3,819,069	$3,706,549	$839,170	$1,092,973
1990	$3,950,782	$3,351,805	$3,248,150	$750,956	$991,183
1991	$4,729,799	$3,717,758	$3,608,310	$846,623	$1,103,896
1992	$4,762,183	$4,214,830	$4,081,862	$936,613	$1,199,611
1993	$5,458,357	$4,828,580	$4,681,492	$1,068,879	$1,402,418
1994	$4,431,367	$3,832,133	$3,715,482	$882,518	$1,144,519
1995	$5,168,319	$4,133,905	$3,993,918	$961,582	$1,244,961
1996	$5,260,199	$4,426,992	$4,279,258	$1,021,787	$1,303,576
1997	$6,196,753	$5,064,783	$4,895,516	$1,192,073	$1,536,463
1998	$6,638,491	$4,994,514	$4,824,765	$1,156,146	$1,489,704
1999	$6,635,902	$4,645,265	$4,481,280	$1,073,338	$1,382,474
2000	$6,745,033	$5,011,016	$4,838,180	$1,147,267	$1,471,505
2001	$6,440,124	$4,659,254	$4,511,846	$1,075,845	$1,390,124
2002	$5,415,275	$4,386,920	$4,239,448	$1,027,357	$1,327,080
2003	$5,112,356	$3,990,709	$3,840,308	$953,197	$1,240,966
2004	$5,359,401	$4,192,396	$4,051,683	$979,442	$1,264,079
2005	$5,619,289	$4,586,313	$4,434,818	$1,058,751	$1,362,777
2006	$5,692,991	$4,898,547	$4,739,224	$1,127,596	$1,465,654
2007	$5,452,789	$4,365,471	$4,219,124	$1,001,879	$1,307,381
2008	$4,471,435	$3,544,531	$3,426,442	$846,360	$1,097,309
2009	$4,504,210	$3,727,461	$3,594,060	$896,159	$1,145,286
2010	$4,250,055	$4,016,346	$3,879,309	$933,097	$1,194,875
2011	$3,951,186	$3,992,801	$3,865,759	$920,733	$1,193,041

Appendix 2

Table A2: Percentiles for distributions of outcomes from figure 15, each row represents the terminal wealth balance for a 40-year accumulation path.

RETIREMENT YEAR	1ST PERCENTILE	5TH PERCENTILE	10TH PERCENTILE	25TH PERCENTILE	MEDIAN	75TH PERCENTILE	90TH PERCENTILE	95TH PERCENTILE	99TH PERCENTILE
1939	$1,564,339	$1,684,413	$1,761,519	$1,901,988	$2,087,684	$2,291,372	$2,503,343	$2,637,411	$2,878,911
1940	$1,461,873	$1,577,053	$1,646,583	$1,775,481	$1,952,582	$2,150,008	$2,349,174	$2,489,767	$2,752,172
1941	$1,402,235	$1,516,871	$1,592,542	$1,729,003	$1,893,121	$2,093,097	$2,283,296	$2,404,224	$2,660,492
1942	$1,418,821	$1,525,155	$1,590,012	$1,722,197	$1,888,560	$2,079,196	$2,264,329	$2,389,749	$2,610,084
1943	$1,543,463	$1,672,648	$1,754,081	$1,899,299	$2,082,216	$2,296,782	$2,506,550	$2,655,383	$2,910,823
1944	$1,500,667	$1,628,320	$1,701,889	$1,842,450	$2,024,008	$2,236,251	$2,440,963	$2,576,946	$2,848,074
1945	$1,509,357	$1,636,800	$1,715,508	$1,850,376	$2,032,692	$2,233,273	$2,446,742	$2,574,565	$2,839,461
1946	$1,612,993	$1,755,423	$1,831,613	$1,980,660	$2,177,469	$2,405,055	$2,620,834	$2,769,498	$3,046,891
1947	$1,900,309	$2,047,051	$2,141,593	$2,304,776	$2,516,189	$2,766,146	$3,013,203	$3,173,838	$3,499,303
1948	$1,650,038	$1,781,441	$1,860,597	$2,003,347	$2,191,486	$2,406,945	$2,626,306	$2,767,771	$3,034,791
1949	$1,711,943	$1,848,045	$1,924,960	$2,085,542	$2,282,812	$2,510,328	$2,730,194	$2,871,166	$3,132,916
1950	$1,860,502	$2,012,331	$2,098,233	$2,265,550	$2,482,799	$2,725,916	$2,973,545	$3,120,841	$3,443,301
1951	$1,944,249	$2,089,954	$2,181,686	$2,356,049	$2,569,465	$2,830,208	$3,080,148	$3,251,593	$3,548,162
1952	$1,760,992	$1,918,668	$2,003,450	$2,173,648	$2,399,121	$2,647,553	$2,905,206	$3,075,299	$3,387,146
1953	$1,776,225	$1,923,013	$2,004,666	$2,175,872	$2,395,983	$2,646,795	$2,894,231	$3,064,965	$3,364,814
1954	$1,939,263	$2,097,406	$2,202,071	$2,387,130	$2,635,565	$2,924,113	$3,215,278	$3,418,079	$3,815,722
1955	$1,967,520	$2,125,196	$2,222,297	$2,415,824	$2,665,848	$2,960,684	$3,244,494	$3,422,627	$3,822,822
1956	$1,982,168	$2,151,584	$2,255,068	$2,444,731	$2,699,801	$2,984,618	$3,277,927	$3,469,294	$3,841,236
1957	$2,112,997	$2,288,740	$2,401,180	$2,604,840	$2,856,770	$3,157,550	$3,458,989	$3,644,492	$4,072,713
1958	$2,264,927	$2,434,655	$2,543,123	$2,757,253	$3,039,932	$3,363,689	$3,700,863	$3,917,824	$4,355,772
1959	$2,203,687	$2,383,597	$2,492,890	$2,698,370	$2,967,477	$3,280,989	$3,609,247	$3,814,736	$4,217,284
1960	$2,125,917	$2,307,533	$2,411,676	$2,614,985	$2,884,225	$3,199,294	$3,516,001	$3,704,743	$4,083,698
1961	$2,343,752	$2,518,315	$2,643,326	$2,863,273	$3,146,972	$3,481,127	$3,825,534	$4,048,797	$4,521,218
1962	$2,104,537	$2,283,446	$2,391,361	$2,599,684	$2,868,648	$3,184,620	$3,507,731	$3,712,310	$4,090,193
1963	$2,119,608	$2,296,950	$2,410,142	$2,621,909	$2,896,567	$3,204,069	$3,518,107	$3,724,417	$4,098,513
1964	$2,097,377	$2,264,326	$2,367,917	$2,572,815	$2,842,428	$3,141,602	$3,452,726	$3,657,426	$4,064,437
1965	$1,885,975	$2,036,503	$2,134,943	$2,330,321	$2,569,005	$2,847,535	$3,130,652	$3,315,566	$3,684,313
1966	$1,746,650	$1,912,238	$2,003,607	$2,184,044	$2,409,882	$2,683,123	$2,954,923	$3,125,833	$3,500,922
1967	$1,811,441	$1,965,569	$2,061,946	$2,249,231	$2,483,006	$2,765,084	$3,037,572	$3,222,418	$3,576,691
1968	$1,819,160	$1,986,638	$2,088,810	$2,274,424	$2,520,026	$2,800,533	$3,101,099	$3,283,489	$3,653,906
1969	$1,854,080	$2,001,447	$2,104,452	$2,291,876	$2,536,116	$2,818,907	$3,107,606	$3,279,200	$3,631,871
1970	$1,963,198	$2,119,700	$2,222,876	$2,418,504	$2,665,898	$2,946,331	$3,241,273	$3,418,470	$3,758,666
1971	$2,030,041	$2,199,792	$2,304,532	$2,495,234	$2,739,722	$3,029,164	$3,316,329	$3,498,233	$3,833,426
1972	$1,995,137	$2,159,750	$2,253,172	$2,446,309	$2,683,842	$2,962,537	$3,242,868	$3,413,639	$3,772,067
1973	$1,458,727	$1,608,069	$1,690,804	$1,857,600	$2,079,797	$2,346,276	$2,618,842	$2,803,399	$3,185,936
1974	$1,221,898	$1,336,596	$1,416,253	$1,573,718	$1,778,886	$2,027,063	$2,283,077	$2,452,383	$2,768,281

Appendix 2 continued

Table A2: Percentiles for distributions of outcomes from figure 15, each row represents the terminal wealth balance for a 40-year accumulation path.

RETIREMENT YEAR	1ST PERCENTILE	5TH PERCENTILE	10TH PERCENTILE	25TH PERCENTILE	MEDIAN	75TH PERCENTILE	90TH PERCENTILE	95TH PERCENTILE	99TH PERCENTILE
1975	$1,301,467	$1,442,097	$1,524,366	$1,694,346	$1,917,494	$2,190,524	$2,469,516	$2,645,554	$2,999,484
1976	$1,310,879	$1,458,859	$1,550,785	$1,729,122	$1,968,572	$2,248,423	$2,541,119	$2,724,419	$3,138,016
1977	$1,406,600	$1,551,774	$1,644,405	$1,820,745	$2,072,925	$2,358,492	$2,666,676	$2,877,790	$3,296,266
1978	$1,419,073	$1,579,026	$1,678,025	$1,854,042	$2,107,719	$2,400,211	$2,705,292	$2,916,048	$3,332,014
1979	$1,539,814	$1,714,392	$1,818,042	$2,030,364	$2,303,739	$2,632,776	$2,979,545	$3,222,371	$3,694,375
1980	$1,755,720	$1,963,097	$2,080,418	$2,315,963	$2,631,729	$3,009,334	$3,412,367	$3,699,058	$4,200,337
1981	$1,713,875	$1,885,672	$1,998,524	$2,227,097	$2,532,462	$2,907,283	$3,317,617	$3,588,960	$4,109,639
1982	$1,836,863	$2,035,526	$2,155,964	$2,408,053	$2,738,467	$3,150,193	$3,574,107	$3,850,233	$4,416,680
1983	$2,011,592	$2,235,499	$2,380,025	$2,663,914	$3,046,410	$3,517,645	$4,022,634	$4,327,043	$4,965,167
1984	$1,987,443	$2,219,313	$2,364,198	$2,645,276	$3,021,428	$3,479,964	$3,941,720	$4,254,357	$4,950,066
1985	$2,259,070	$2,514,169	$2,670,150	$3,005,946	$3,445,603	$3,991,408	$4,611,873	$4,993,037	$5,861,333
1986	$2,376,838	$2,661,446	$2,842,304	$3,206,503	$3,705,680	$4,296,258	$4,975,175	$5,382,544	$6,370,989
1987	$2,084,572	$2,364,611	$2,538,687	$2,861,177	$3,303,546	$3,832,046	$4,413,712	$4,797,664	$5,661,461
1988	$2,255,809	$2,539,258	$2,717,936	$3,075,344	$3,544,180	$4,139,037	$4,770,750	$5,171,576	$5,916,347
1989	$2,353,144	$2,654,642	$2,841,695	$3,209,815	$3,706,464	$4,302,788	$4,924,269	$5,343,547	$6,318,769
1990	$2,039,721	$2,305,346	$2,475,456	$2,804,779	$3,247,994	$3,795,962	$4,354,179	$4,752,415	$5,490,243
1991	$2,246,627	$2,545,153	$2,730,749	$3,105,909	$3,608,273	$4,209,805	$4,851,062	$5,272,645	$6,174,760
1992	$2,595,644	$2,933,900	$3,133,360	$3,539,178	$4,081,829	$4,738,789	$5,468,636	$5,955,665	$6,949,550
1993	$3,007,661	$3,357,169	$3,588,468	$4,048,018	$4,681,228	$5,450,436	$6,267,301	$6,782,899	$7,945,798
1994	$2,308,182	$2,624,070	$2,812,530	$3,186,160	$3,715,466	$4,330,679	$5,024,907	$5,465,902	$6,418,562
1995	$2,505,878	$2,813,855	$3,018,362	$3,434,035	$3,993,873	$4,678,996	$5,412,183	$5,937,037	$6,903,931
1996	$2,652,967	$3,012,890	$3,253,106	$3,696,393	$4,279,224	$4,999,969	$5,801,969	$6,339,504	$7,442,757
1997	$3,060,626	$3,446,129	$3,702,235	$4,200,486	$4,895,205	$5,736,949	$6,622,920	$7,285,705	$8,667,881
1998	$3,043,080	$3,392,098	$3,662,780	$4,160,464	$4,824,566	$5,650,168	$6,570,856	$7,170,796	$8,410,831
1999	$2,828,761	$3,197,069	$3,411,275	$3,875,605	$4,481,135	$5,258,078	$6,083,343	$6,657,549	$7,793,626
2000	$3,094,457	$3,468,941	$3,703,808	$4,182,929	$4,838,148	$5,654,434	$6,574,957	$7,126,916	$8,349,384
2001	$2,810,279	$3,190,012	$3,417,554	$3,880,137	$4,511,686	$5,270,262	$6,106,688	$6,668,939	$7,741,116
2002	$2,629,053	$2,982,089	$3,203,779	$3,643,282	$4,239,360	$4,970,363	$5,782,081	$6,292,419	$7,386,853
2003	$2,374,569	$2,695,101	$2,896,868	$3,300,967	$3,840,172	$4,541,933	$5,275,027	$5,779,018	$6,745,328
2004	$2,517,865	$2,853,033	$3,063,557	$3,477,362	$4,051,680	$4,741,440	$5,507,749	$6,027,425	$7,079,526
2005	$2,749,203	$3,148,332	$3,377,447	$3,821,664	$4,434,650	$5,184,440	$6,002,221	$6,521,983	$7,632,553
2006	$3,000,573	$3,357,526	$3,615,474	$4,078,734	$4,738,989	$5,544,388	$6,383,353	$7,007,943	$8,270,100
2007	$2,670,107	$2,993,034	$3,210,320	$3,640,209	$4,219,066	$4,947,590	$5,727,828	$6,229,056	$7,290,805
2008	$2,099,916	$2,384,381	$2,578,600	$2,931,266	$3,426,442	$4,028,575	$4,658,581	$5,078,963	$6,059,699
2009	$2,197,566	$2,507,709	$2,708,922	$3,083,831	$3,594,056	$4,229,117	$4,916,232	$5,416,196	$6,421,506
2010	$2,438,126	$2,737,959	$2,933,810	$3,347,508	$3,879,078	$4,542,383	$5,261,147	$5,718,282	$6,750,914
2011	$2,424,586	$2,730,901	$2,935,151	$3,328,848	$3,865,317	$4,521,889	$5,230,972	$5,682,110	$6,683,261

Appendix 3

The study uses nominal rates of return in its analysis. Nominal returns were used as the primary methodology because they have precedent in the retirement savings literature (Basu and Drew 2009a; Basu, Byrne and Drew 2011) and also in the broader time diversification literature (e.g. Hickman et al. 2001; Guo and Darnell 2005). Another important consideration for this study was to use history as a guide. To capture historical returns in their absolute form, the study required that historical inflation be included in the calculations. Recent literature suggests that inflationary values also drive market returns through behavioural finance. For instance, markets are commonly referred to as having a floor (or ceiling) which is a psychological barrier for investors (see Li and Yu 2012).[32] These market levels are based on nominal values, thus inflation is also a driver of returns and is not just reducing the value of money in an economy.

A further challenge in using real returns relates to the practical question of 'what is inflation?' Inflation figures are commonly found by using the Consumer Price Index (CPI).[33] The DMS database uses inflation measures from the GDP deflator (1900–1901), the Retail Price Index (1902–1948) and the CPI (1948–2011). Therefore, researchers are challenged by the generalisation of inflation (and the accuracy of its representation) when applied across multiple asset classes. However, while noting the various issues in the nominal-versus-real debate, there is merit in undertaking a confirmatory analysis using real returns. All of the experiments conducted in the body of the study have been replicated using real returns and contributions.[34] All of the original assumptions outlined in the study are held constant for this analysis. However, to keep in line with the reduction in inflation, the salary growth rate is reduced to two per cent per annum.[35] The key result from this replication using inflation-adjusted data is that it confirms the major findings of this study and, in some instances, points to the problem of sequencing risk being potentially an even greater issue for retirement outcomes.

Table A1 illustrates the summary statistics for the real return analysis. The results show a reduced annual long run average return by four per cent.

Table A3: Summary statistics for the default strategy's real returns (1900–2011)

VARIABLE	ASSUMPTION
Mean	6%
Standard deviation	12%

The analysis of the portfolio size effect using real returns corroborates the nominal findings. Figure A1 (a replica of figure 7) illustrates the cumulative contributions divided by the total portfolio size each year.

The results presented in figure A1 (a replica of figure 7) show that the age at which the investor's first 40-year accumulation path reaches the 50 per cent level (cumulative contributions/portfolio size) is not dissimilar to that of nominal figures. The first path occurs at approximately 34 years of age, identical to the nominal return analysis. The main study found an 80/20 rule of thumb when using nominal returns. The real return analysis supports this rule of thumb (albeit with a much wider distribution), with the average cumulative contributions in the final 10 years approximately 40 per cent of total portfolio size. In short, this is a 60/40 rule, versus an 80/20 rule using nominal data.

Figures A2 and A3 (replicas of figures 8 and 9) illustrate the return volatility over time when using real returns. Figure A2 shows the rolling three-year equity volatility from 1900 to 2011 while figure A3 provides a colour-coded histogram of the default strategy's annual real returns. As expected, both figures have a strong resemblance to those which are derived using nominal returns. Figure A3 shows the tails are still populated by the returns experienced later in the century and that the left tail of the distribution is more heavily populated.

32. These market floors (or ceilings) are not only seen in terms of total market capitalisation but also on an individual stock basis when observing the stocks 52-week highs and lows (see Li and Yu 2012). Psychological barriers are also found in international exchange rates, which fluctuate somewhat with respect to the differing levels of individual country inflation (see Mitchell and Izan 2006).

33. The CPI is a measure of the change in price of a basket of consumer goods over time. There are multiple calculation issues which arise when calculating the CPI (see Braithwait 1980; Manser and McDonald 1988; Lebow and Rudd 2003). There is also a question about which is a better measure of inflation — the CPI, which estimates consumer inflation, or the Producer Price Index (PPI) (see Tsiaplias 2008).

34. In the interest of brevity, only the key tables and figures are provided in this appendix, but others are available on request.

35. The value of two per cent real wage growth is commonly used in the literature (see, for example, Byrne etal. 2006; Basu and Drew 2010).

Figure A1: Total cumulative contributions as a percentage of total portfolio balance for all 40-year accumulation paths from 1900 to 2011 using the default strategy's annual real returns (n=73)

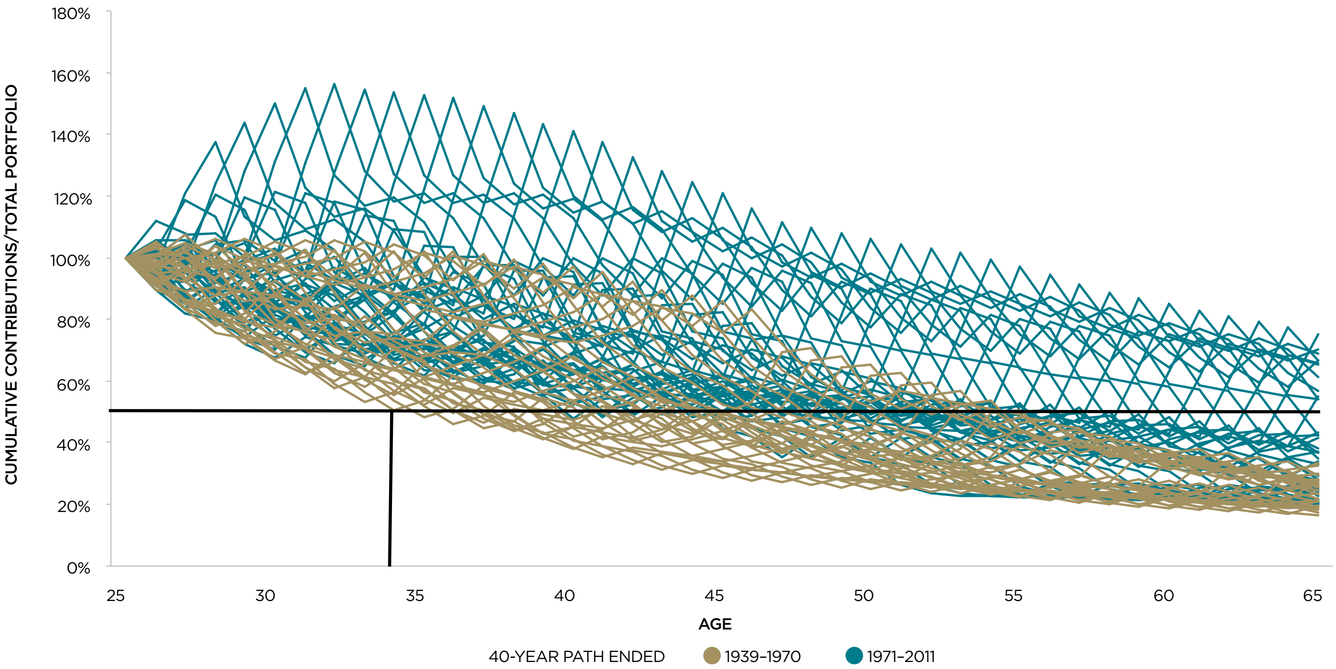


Figure A2: Rolling three-year Australian real return equity volatility from 1900 to 2011

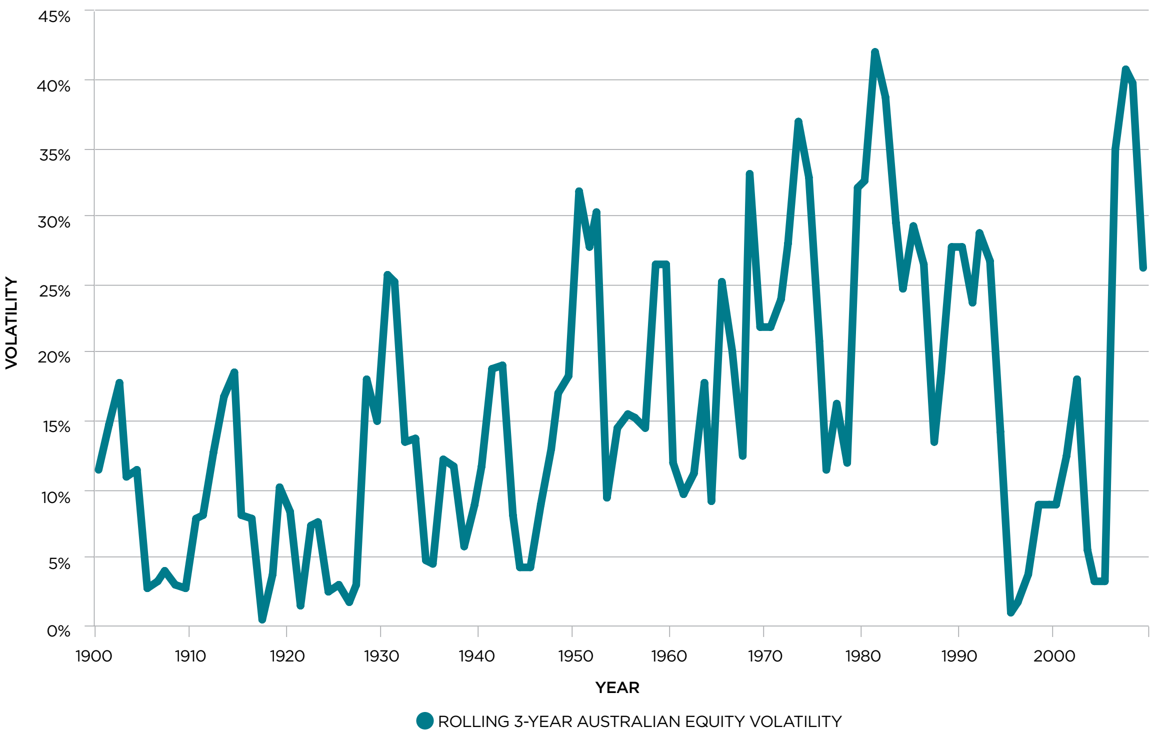


Figure A3: Histogram of the default strategy's annual real returns (1900–2011)

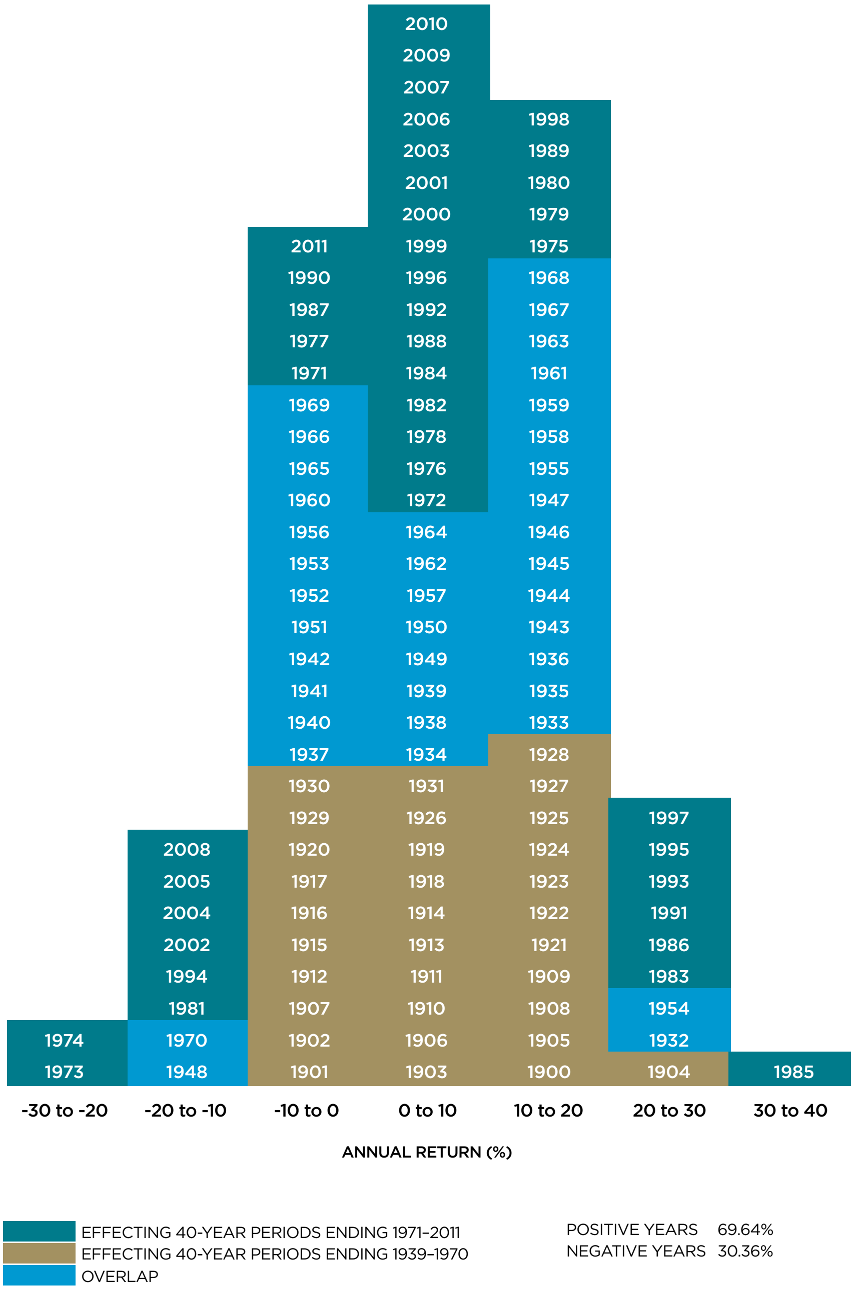
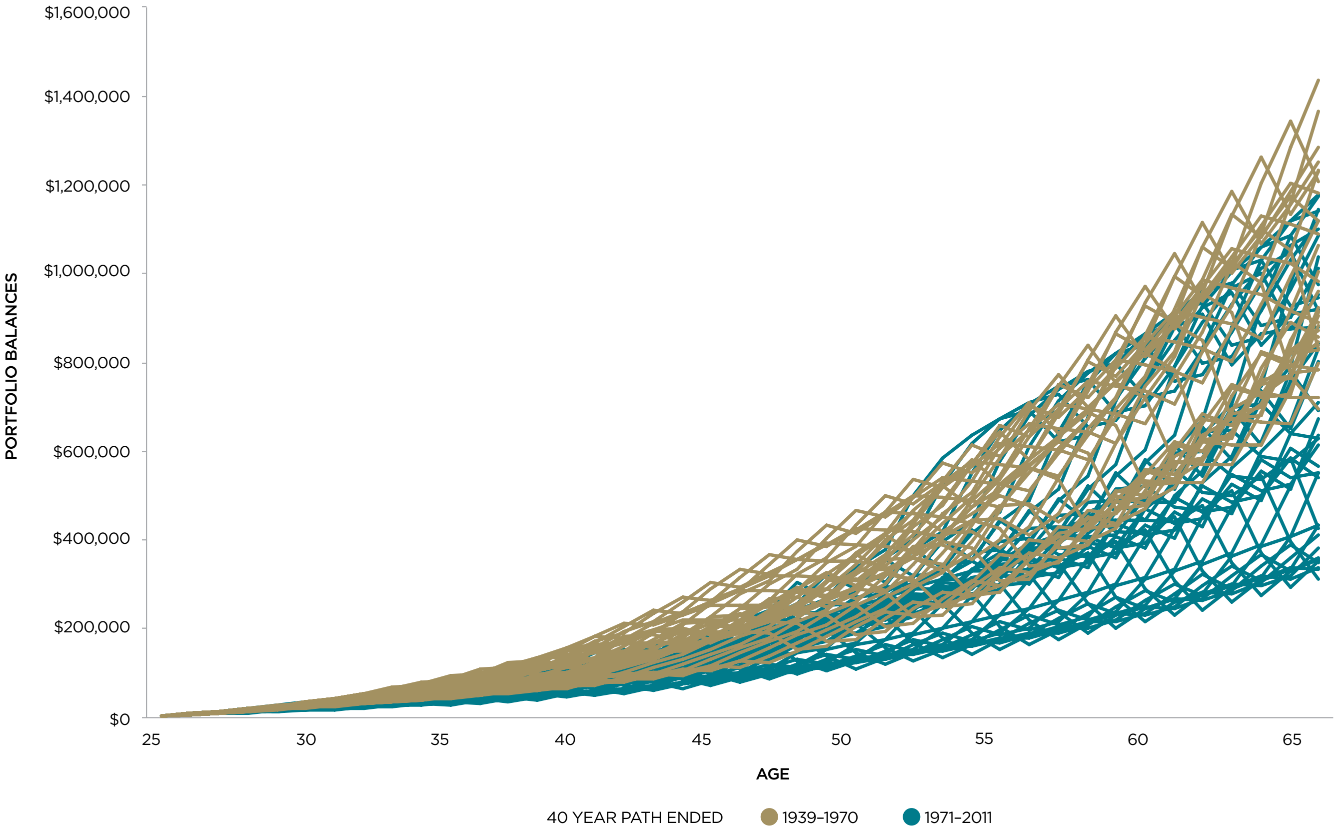


Figure A4: Every 40-year accumulation path from 1900 to 2011 using the default strategy's real annual returns (n=73)



When observing how the portfolios track through time, some differences in the order can be observed when comparing nominal and real returns. However, the main findings of the paper remain consistent. Figure A4 (a replica of figure 10), shows every 40-year accumulation path from 1900 to 2011; using real returns some of the red paths (representing 40-year paths ending from 1939 to 1970) outperform the blue paths (representing 40-year paths ending from 1971 to 2011). However, the main finding of the paper is that the range between the best and worst paths has been increasing over time; this is corroborated with the real return analysis, as seen in figure A4.

Figure A5: Heat map of the default strategy's annual real returns for every 40-year accumulation path from 1900 to 2011 (n=73)

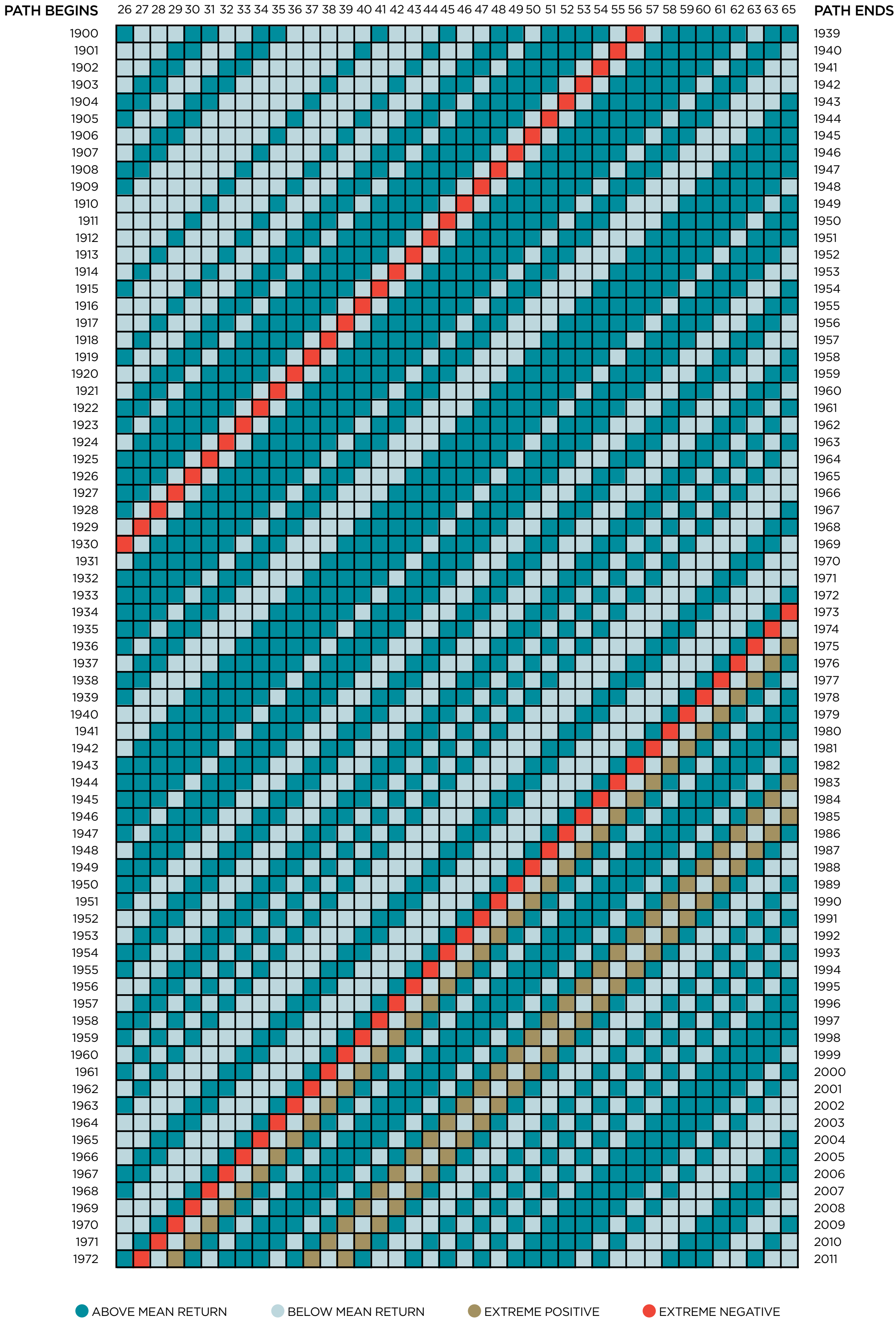
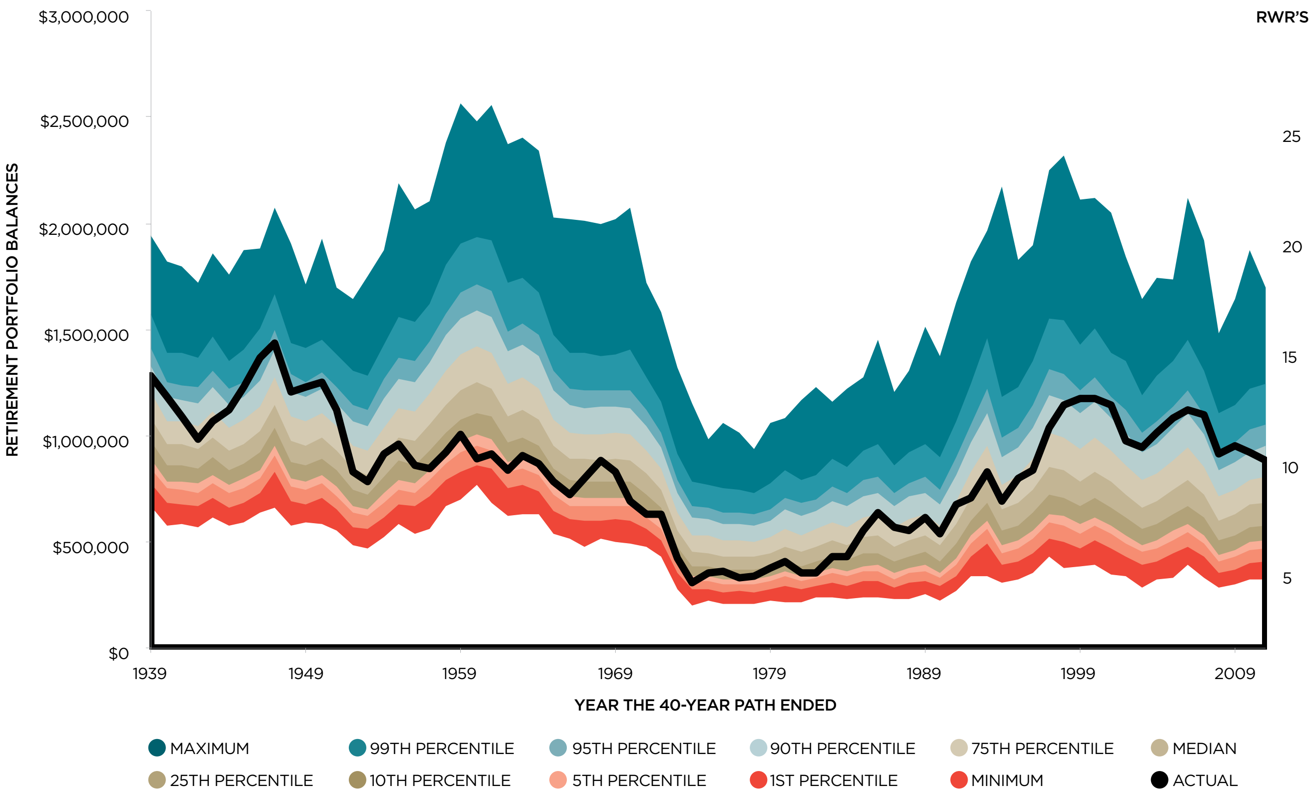


Figure A5 (a replica of figure 11) illustrates a heat map of the real returns. The colour coding follows the same methodology as used in the study.

Figure A6: The default strategy's annual real returns were used to find every 40-year accumulation path from 1900 to s2011. These were shuffled via a bootstrap method 10,000 times each to simulated 10,000 final portfolio balances.



Finally, figure A6 (a replica of figure 15) shows the shuffled bootstrap of every 40-year accumulation path. The same methodology is followed as in figure 15 in the study. The variability illustrated in figure A6 reflects the main themes resulting from using nominal returns.

The striking features of the real return analysis are the actual realised extremes. For example, the worst 40-year accumulation path is the 40-year path ending 1974 and this path falls into the fifth percentile in the real return analysis.

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