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UNDERSTANDING THE LEVERAGED LIFE CYCLE INVESTMENT STRATEGY FOR DEFINED-CONTRIBUTION PLAN INVESTORS

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ABSTRACT

We investigate whether the leveraged life cycle strategy, in which leverage is used to buy stocks when investors are young, is able to produce better retirement outcomes than other investment strategies that are currently offered by defined contribution plan providers and those suggested in the literature. Using both historical and bootstrap simulations for the period of 1900-2011 in the US, we find that the leveraged life cycle strategy has an ability to reduce risk, though this ability is relatively insignificant. Further, the leveraged life cycle strategy shows a comparative advantage over the balanced strategy. However, the leveraged life cycle strategy produces retirement outcomes inferior to conventional life cycle strategy, and demonstrates significant inferiority when compared to dynamic life cycle strategy.

Introduction

Population ageing with its rising proportion of retirees, one of the most distinctive demographic events of the twenty-first century, has put considerable pressure on government social security programs. This situation has led governments to encourage funded private retirement plans, also known as defined contribution (DC) plans, where participants are responsible for building up retirement wealth through mandatory or voluntary contributions in their retirement account. This growing trend in DC plans has highlighted the importance of participants taking more control over the investment of their plan assets. This investment strategy is important as it defines future investment returns on their plan assets, which will determine retirement wealth adequacy at the end of the participant's working life. Although an individual's retirement wealth adequacy is a function of many parameters, investment strategy has been considered to be the most influential factor (Yuh, *et al.*, 1998). This defining feature leads to much debate about the current design of investment strategies that are adopted by DC plans.

Lifestyle (or target risk) and life cycle (or target date) strategies have long been recognised by DC plan investors. Lifestyle investment strategy, motivated by the seminal work of Modern Portfolio Theory (Markowitz, 1952), is built on the idea of "risk-based investing", or the notion that the fraction of savings allocated to stocks should be a function of investor's risk tolerance, and independent of their investment horizon (Merton, 1969; Samuelson, 1969). Life cycle investment strategy is built on the idea of "age-based investing", or the notion that investors should allocate a larger portion of their long-term investment to stocks or other risky assets when they are young and have a relatively long investment horizon, gradually shifting this allocation towards less risky assets as they approach retirement (Malkiel, 1996). Unlike lifestyle strategy, a life cycle strategy does not keep its target mix constant over time. Instead, it deterministically changes the target mix that is held in stocks and bonds according to a predefined "glide path", which gradually tilts the assets mix away from stocks and other risky assets towards less risky assets such as bonds and cash as investors approach retirement. Life cycle strategy has gained popularity with US defined contribution (DC) plan investors in recent years. Over the past 10 years, assets in life cycle funds have grown from $71 billion in 2005 to $763 billion in 2015 in the U.S. (Morningstar, 2015).

A number of studies suggest that life cycle funds may be a reasonable choice for investors (Hickman, *et al.*, 2001; Pang and Warshawsky, 2010; Pfau, 2010). However, extensive research has documented the inferior risk-return characteristic of life cycle strategy. Shiller (2005) indicates that life cycle strategy may not be optimal for investors who are saving for retirement. Poterba, *et al.* (2006) suggests that the retirement wealth distribution associated with life cycle investment strategies is similar to strategies that allocate a constant portfolio share to stocks. Schleef and Eisinger (2007) find little evidence that life cycle strategy either enhances or detracts from the overall performance of lifestyle strategy. Basu and Drew (2009) show that when moving away from stocks to low-return asset classes as the size of the retirement portfolio grows larger, investors may forgo the opportunity to earn higher returns. Lewis (2010) suggests the traditional approach of life cycle strategy may be too simplistic and further innovations may be needed.

Although lifestyle and life cycle strategies are designed to help investors achieve retirement wealth adequacy, they have been widely criticised for their poor performance during the period of the 2008 Global Financial Crisis (Halonen, 2009). This crisis has highlighted the problem of the deterministic fixed glide path of these investment strategies on the terminal wealth accumulation for DC plan investors, and the uncertainty as to whether those retirement savings would provide adequate retirement wealth, especially for those close to retirement. As a result, another stream of literature questions the deterministic nature of life cycle switching, and supports the idea of dynamically adjusting asset allocation as the retirement date approaches. Yoon (2010) explores a new approach to define the glide path of target date funds, which is to start with allocating a risk budget for each target date.

According to the pre-defined risk budget, the asset allocation of target date funds can be obtained by explicitly incorporating the term structure of risk. The findings show that the target risk-based glide path can afford larger exposure to stocks in early years, but it reduces stock allocation more aggressively than target-date funds as the target date draws near. Basu, *et al.* (2011) propose a dynamic life cycle strategy that is flexible in adjusting allocation between growth and conservative assets as the retirement date approaches, depending on the cumulative portfolio performance relative to a set target. Basu, *et al.* (2011) find that, compared with dynamic life cycle strategy, life cycle strategy produces inferior wealth outcomes for investors.

More recently, researchers have investigated investment strategies employing a leverage factor. Ayres and Nalebuff (2013) propose a leveraged life cycle strategy that invests a constant percentage of the present value of lifetime saving in stocks. This strategy is built on the notion of using leverage when the present value of future contribution is large relative to current savings, and then reducing leverage and finally un-leverage as current savings grow and the present value of future contributions declines[1]. Specifically, a leveraged life cycle strategy contains three phases. In phase one, investors' retirement savings are leveraged at 2:1 and fully invested in stocks[2]. In phase two, investors start to deleverage when the current savings exceed 20 per cent of discount lifetime savings (discounted at a real risk-free rate of 2.56%), until the current savings hit the desired level of market exposure, set at 50 per cent of discount lifetime savings allocated to stocks[3]. In phase three, investors maintain the market exposure at the desired level (50%), and the leverage is no

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[1] The recommendation from the Merton (1969) and Samuelson (1969) life cycle investment theory is to invest a constant fraction of wealth in stocks. However, this study states that the mistake in translating this theory into practice is that young people invest only a fraction of their current savings in stocks, instead of the discounted lifetime savings. For example, those who invest 100 per cent in stocks of current savings in their 30s, are still likely to have less than 10 per cent of their lifetime savings if their risk aversion led them to invest 60 per cent of their lifetime savings.

[2] The reason for using 2:1 leverage is that the incremental cost of borrowing more than 2:1 leverage increases rapidly and exceeds the expected returns quickly.

[3] To choose 50 per cent stocks allocation is following Merton (1969), that the optimal or target stock allocation λ is determined by: $\lambda = (z - r) / (\sigma^2 * \gamma)$, where z is the expected future stocks returns, r is the relevant interest rate, σ^2 is the expected variance of future stock returns, and γ is the investor's constant relative risk aversion. Assume that for a typical investor who has a risk aversion of 4, the geometric mean of stock returns is 8.83 per cent with standard deviation of 14.3 per cent, and the relevant interest rate for the leveraged life cycle strategy is the margin rate, which is the geometric mean of 4.71 per cent call money rate plus 30 basis points. The optimal percentage target is then about 50 per cent stock allocation.

longer required. According to Ayres and Nalebuff, a leveraged life cycle strategy generates the same mean retirement wealth as the constant 74 per cent stock allocation strategy, but with a 20 per cent reduction in the standard deviation of retirement wealth. Compared to the traditional un-leveraged life cycle strategy that starts with 90 per cent stock allocation and decreases linearly to 50 per cent, the leveraged life cycle strategy leads to an 11.5 per cent improvement in certainty equivalent.

Both risk reduction and superior returns results provided by the leveraged life cycle strategy may suggest that a leveraged life cycle strategy represents an asset allocation approach worthy of investigation. Further, using the factor of leverage in the design of DC plan's investment strategy is relatively new. An important question then emerges: Is the leveraged life cycle strategy able to produce retirement wealth outcomes superior to other strategies that are currently offered by DC plan providers and those suggested in the literature in the US market? Although extensive research has documented the evaluation of life cycle, lifestyle, dynamic, and leveraged strategies for DC plan investors (Basu and Drew, 2010; Sharma, *et al.*, 2015; Pfau, 2010), there is no prior study investigating the comparative performance of leveraged life cycle strategy and other strategies that are currently offed by DC plan providers and those suggested in the literature.

This study is motivated to extend this issue by investigating whether the leverage life cycle strategy that is proposed by Ayres and Nalebuff (2013), is able to produce better retirement outcomes over the balanced, conventional life cycle, and dynamic life cycle strategies. Any results uncovered will provide a valuable contribution to the body of pension finance literature by embarking on a robust analysis of the balanced strategy, conventional life cycle strategies, dynamic life cycle strategies and leveraged life cycle strategies. Findings of our study have the potential to add value from investors' perspectives. Investment strategy is critically important for institutional investor's returns. They need to determine the most appropriate investment decision. The outcomes of this study may enhance investors' ability to improve fund returns by choosing different investment strategies. This study may be regarded as unique insofar as it is the first to synthesise the leveraged life cycle strategy with other investment strategies that are currently offered by DC plan providers, as well as those suggested in the literature.

By applying both historical and bootstrap simulations for the period 1900-2011, we show that leveraged life cycle strategy has an ability to reduce risk, though the risk reduction ability is relatively insignificant. Further, leveraged life cycle strategy demonstrates a comparative advantage over the balanced strategy. However, leveraged life cycle strategy produces retirement outcomes that are inferior to conventional life cycle strategies, and demonstrates significant inferiority when compared to dynamic life cycle strategies.

The rest of the paper is organised as follows. Section 2 describes the data and their summary statistics; Section 3 introduces the methodology; Section 4 presents the results; and Section 5 concludes the paper.

Data

The asset class return data used in this study comes from the dataset of global returns compiled by Dimson, Marsh, and Staunton (2002), which is commercially available from Morningstar and Ibbotson Associates. An updated version of this dataset, providing global returns from 1900 to 2011, is used in this study. We use this dataset because it is the only authentic dataset available for long-term nominal returns of stocks, bonds and bills of the US market[4]. It covers a period of more than 100 years that will have captured both favourable and unfavourable returns on individual asset classes over the entire twentieth century.

This long-term dataset allows us to investigate a large number of overlapping 40-year paths in the historical simulation, and provides a rich source of data for the bootstrap method in the meantime. For the purpose of parsimony, the nominal annual returns of US stocks and bonds are obtained from this dataset, where stocks are used as a proxy for growth assets and bonds are used as a proxy for defensive assets[5], while bills are used as a proxy for risk-free assets when we construct the leveraged life cycle strategy.

Table 1: Descriptive Statistics for the US Nominal Returns Data (1900-2011)

	Stocks	Bonds	Bills
Geometric Mean (%)	9.30	5.00	3.90
Arithmetic Mean (%)	11.27	5.38	3.95
Median (%)	13.78	3.67	4.07
Maximum (%)	57.09	40.36	14.71
Minimum (%)	-43.54	-14.90	-0.02
Standard Deviation (%)	19.97	8.87	2.82
Skewness	-0.37	1.22	0.73
Kurtosis	2.84	5.40	4.02
Jarque-Bera Statistic	2.62	54.55*	14.72*

Note: This table presents the summary statistics of nominal annual returns data for US stocks, bonds, and bills from 1900 to 2011. Geometric and arithmetic mean, standard deviation, median, maximum, and minimum are expressed in percentage. Skewness, Kurtosis, and Jarque-Bera statistic are numbers.

**represents statistical significance at the 5 per cent level.*

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[4] Another reason is that it is important to retain the consistency with the proxy assets used in Ayres and Nalebuff (2013) for a comparison purpose.

[5] We acknowledge that international stocks, international bonds, and treasury inflation protected securities represent significant compositions of the portfolio construction. We do not include them in our study because of the paucity of reliable long-term return data.

Table 1 presents the descriptive statistics of the nominal asset class returns for the period 1900-2011. As expected, the lower risk is associated with bonds; the higher return is associated with stocks. For the US market, stocks provide a geometric mean return of 9.30 per cent, an arithmetic mean return of 11.27 per cent, with a standard deviation of 19.97 per cent. These high returns and high risks are contrasted with bonds, which has a geometric mean return of 5.0 per cent, an arithmetic mean return of 5.38 per cent, with a standard deviation of 8.87 per cent. Table 2 presents the correlation coefficients between the US nominal returns of stocks and bonds. The low correlation between stocks and bonds, which is 0.0665, provides a potential for diversification benefits.

Table 2: Correlation Matrix

US	Stocks	Bonds
Stocks	1	0.067
Bonds	0.067	1

Note: This table presents the correlation coefficients between the US nominal returns of stocks and bonds.

Methodology

An accumulation model is developed for a hypothetical DC plan investor before commencing the analysis of different investment strategies. Following Basu and Drew (2010), the terminal wealth of a DC plan portfolio is given by:

$$W = K \sum_{t=0}^{R-1} (1-p_t)\, S_t (1+r_t) \prod_{u=t+1}^{R-1} (1+r_u) \qquad (1)$$

where W is the terminal wealth at the time of retirement, K is the contribution rate, p_t is probability of unemployment in year t, S_t is the annual salary in year t, r_t is the rate of investment return earned in year t, and R is the number of years in the plan before retirement.

In order to estimate W, we need to model the contribution cash flows and investment returns for each period. Contribution cash flows depend on salary, contribution rate, and the probability of unemployment in any period, as cash flows of plan contributions are likely to be affected by the employment states. The salary in any period depends on the starting salary, salary growth rate, and the number of periods elapsed since the commencing employment. This is given by:

$$S_t = S_0 \, (1+g)^{\mathrm{t-1}} \qquad (2)$$

where S_0 is the starting salary of the plan participant, and g is the salary growth rate.

Investment returns depend on the returns of individual asset classes in the portfolio and weights assigned to them. Weights are determined by the investment strategy of the plan.

Therefore:

$$r_t = \sum w_{i,t} r_{i,t} \tag{3}$$

where $w_{i,t}$ is the weight assigned to the i^{th} asset in month t, and $r_{i,t}$ is the return on the i^{th} asset in month t.

The investment strategy ($w_{i,t}$), our primary variable of interest, decides weights of different asset classes in the portfolio. If we assign values to other variables in the accumulation model, the investment strategy ($w_{i,t}$) solely determines the variation in retirement wealth accumulated by an individual at the end of the working life. Probability of unemployment can be modelled as a binary variable. Table 3 outlines key assumptions attributed to the hypothetical DC plan investor[6]. For illustrative purposes, the investor is assumed to be fully employed during the entire investment horizon, and therefore contributions will be a constant percentage of salary over time. Contributions are assumed to be credited to the investor's account at the end of each year. We also ignore any taxes payable on investment returns and any transaction costs that may be incurred in managing the investments.

Table 3: Key Assumptions

Variable	Assumption
Starting Balance	$0
Starting Salary	$25,000
Salary Growth Rate	4% p.a.
Contribution Rate	9% p.a.
Starting Age	25
Retirement Age	65

Note: This table outlines key assumptions attributed to a hypothetical DC plan investor.

The objective of this study is to investigate whether the leveraged life cycle strategy is able to produce better retirement outcomes than those of other investment strategies that are currently offered by DC plan providers and those suggested in the literature. Following the leveraged life cycle strategy proposed by Ayres and Nalebuff (2013), we assume a two-asset world where stocks are the growth asset and bonds are the defensive asset, the investor's optimal target percentage is 50 per cent stocks and 50 per cent bonds allocation, and the maximum leverage is at 2:1. The leveraged life cycle strategy generally contains three phases. (1) Investors' retirement savings are leveraged at 2:1 and fully invested in stocks. (2) When the current savings exceed 20 per cent of discounted lifetime savings (discounted at risk-free rate that is represented by the mean of bills' return), investors start to deleverage as savings continue to rise, until the current savings hit the

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[6] The rationale of these assumptions is explained in detail by Basu and Drew (2009) and Basu, *et al.* (2011).

desired level of market exposure, which is 50 per cent of discount lifetime savings allocated to stocks. (3) Investors maintain the market exposure at the desired level (50/50), and the leverage is no longer required.

With respect to the margin interest, we examine two different rates: risk-free rate plus 100 basis points and risk-free rate plus 200 basis points[7]. Based on two different margin interest rates, we construct two leveraged life cycle strategies, namely LLC100 and LLC200, where LLC100 represents the aggressive leveraged life cycle strategy and LLC200 represents the conservative leveraged life cycle strategy. For the purpose of doing a comparative analysis, this study examines nine different prototypical investment strategies that consist of three constant lifestyle strategies, two life cycle strategies, two dynamic strategies, and two leveraged life cycle strategies. Table 4 outlines the details of each strategy.

Table 4: Investment Strategies

	Investment Strategy Symbol	**Description**
Lifestyle strategy	100 stocks	100% stocks allocation
	100 bonds	100% bonds allocation
	Balanced	60% stocks and 40% bonds allocation
	LC90	Modelled after Vanguard Target Retirement Funds. Start with 90% stocks, 10% bonds allocation for the first 20 years, and then decrease the stock weights 2% annually in a linear pattern to reach an allocation of 50% stocks and 50% bonds at retirement.
	LC95	Modelled after Principle Funds. Start with 95% stocks, 5% bonds allocation, and experience a gradual decline 1% annually away from stocks to reach an allocation of 56% stocks and 49% bonds at retirement.
	DLC2020	Start with 100% stocks for the first 20 years. At the end of 20 years, if the target is achieved, the assets are switched to a portfolio comprising of 80% stocks and 20% fixed income; otherwise, remain invested in 100% stocks. This process is also carried out for the next 10 years. In the last 10 years, the assets are switched to a portfolio of 60% stocks and 40% fixed income if the target is achieved. Otherwise, remain invested in 100% stocks.
	DLC3010	Similar to above, except that it starts with 100% stocks for the first 30 years. This process is carried out for the next 5 years. In the last 5 years, the assets are switched to a portfolio of 60% stocks and 40% fixed income if the target is achieved. Otherwise, remain invested in 100% stocks.

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[7] Ayres and Nalebuff (2013) use broker call money rates plus 30 basis points as the margin interests. We are using risk-free rate plus 100 and 200 basis points because of the unavailability of the broker call money rates data. We also believe that portfolio selection is built on the assumption that borrowing at risk-free rate, and using risk-free rate plus 100 basis points and 200 basis points will fairly demonstrate the cost effect of leverage.

Table 4: Investment Strategies (continued)

	Investment Strategy Symbol	Description
Leveraged life cycle strategy	LLC100	Start with leverage at 2:1 and fully invested in stocks. When the current savings exceed 20% of discount lifetime savings; investors start to deleverage as savings continue to rise, until the current savings hit the 50% stock allocation. After that, investors maintain the market exposure. Risk-free rate plus 100 basis points is used as the margin rate.
	LLC200	Similar to above, except that, instead of using risk-free rate plus 100 basis points as the margin rate, it uses a risk-free rate plus 200 basis points as the margin rate.

Note: This table describes different investment strategies that are examined in this study.

Historical and bootstrap simulation methods are employed in this study. The historical simulation has a long history in the pension finance studies (Shiller, 2005). Sometimes referred to as rolling periods, it calculates end-of-the-period portfolio values from historical stocks and bonds returns. At the completion of the analysis of a hypothetical worker's whole working life period, the sample whole period is rolled forward by one year, and another analysis is then conducted. In this study, stock and bonds returns from 1900 to 2011 devise 73 separate draws for our hypothetical investor, who experiences 40 years' returns. According to our assumptions, the hypothetical worker first starts working in 1898 and the first year's ending portfolio value is only the nine per cent contribution that is deducted from salaries. The second year's ending portfolio value is the portfolio returns plus the second year's contribution. The process of calculating annually rebalanced portfolio value continues through the whole working life period. At the completion of the first analysis of 40 years' period, the first year's returns are dropped and the 40 years' period sample is moved forward by one year. The process of dropping the earliest year and adding the next year's returns continues until the available stocks and bonds returns data are exhausted. The portfolio is rebalanced at the end of each year to maintain the targeted asset allocation. This method has, however, been widely criticised for relying heavily on the returns from the middle years of the whole dataset (Cooley, *et al.*, 2003). For instance, the data of 1939 and 2011 have been used only once.

Therefore, we resort to an alternative bootstrap simulation method to further investigate the retirement wealth outcomes of different strategies. The bootstrap simulation method, introduced by Efron (1979), is a technique that involves resampling row vectors with replacements to generate synthetic time series. By resampling row vectors, this method can retain the cross-correlation between asset class returns. It has been used in a number of studies in the pension fund literature (Basu and Drew, 2009; Basu, *et al.*, 2011; Liu, *et al.*, 2011). In this study, we follow a random draw with replacement from the asset class returns. The historical asset class returns data is randomly resampled with one replacement to generate asset class return vectors for each year of 40 years. Asset class return vectors are then combined with asset classes weights in the portfolio to generate portfolio returns. This process is iterated 10,000 times. Hence, each asset allocation has 10,000 investment return paths resulting in 10,000 wealth outcomes at the end of the 40-year horizon.

The Retirement Wealth Ratio (RWR) is used as the measure of retirement wealth. This measure, originated by Basu and Drew (2010), is calculated by dividing terminal wealth to terminal salary. The rationale behinds the RWR is that the participant's post-retirement income expectations are closely linked to their immediate income before retirement.

Results

Our comparison of different strategies starts with Table 5, which shows the distribution for wealth accumulation outcomes at retirement by using the historical simulation method, expressed as RWRs. The distribution of RWRs for different asset allocation strategies provides us a fair view of their relative appeal to the retirement investor. For any of these parameters, a higher value generally indicates a more attractive strategy. In addition to mean and median, the first and third quartile estimates of the distribution are examined. In order to compare leveraged life cycle strategies with constant, life cycle and dynamic investment strategies, all asset allocation strategies are separated into three panels. Panel A reports the comparison of leveraged life cycle and constant asset allocation strategies. Panel B reports the comparison of leveraged life cycle and conventional life cycle asset allocation strategies. Panel C reports the comparison of leveraged and dynamic asset allocation strategies.

Table 5: Distribution Parameters of Retirement Wealth Ratio (RWR)

Investment Strategy	Mean	Median	75th Percentile	25th Percentile
PANEL A (leveraged life cycle versus lifestyle investment strategies)				
LLC100	12.74	10.71	17.46	9.10
LLC200	12.54	10.57	17.11	9.00
Balanced	11.13	9.82	14.54	7.72
100 Stocks	17.26	17.87	21.20	13.72

Table 5: Distribution Parameters of Retirement Wealth Ratio (RWR) (continued)

Investment Strategy	Mean	Median	75th Percentile	25th Percentile
100 Bonds	5.53	3.76	8.12	2.91
LLC200 - Balanced	**1.41**	**0.75**	**2.57**	**1.28**
PANEL B (leveraged life cycle versus life cycle investment strategies)				
LLC100	12.74	10.71	17.46	9.10
LLC200	12.54	10.57	17.11	9.00
LC90	13.33	12.76	17.24	9.72
LC95	12.66	11.32	16.63	9.54
LLC200 - LC90	**-0.79**	**-2.19**	**-0.13**	**-0.72**
LLC200 - LC95	**-0.12**	**-0.75**	**0.48**	**-0.54**
PANEL C (leveraged life cycle versus dynamic life cycle investment strategies)				
LLC100	12.74	10.71	17.46	9.10
LLC200	12.54	10.57	17.11	9.00
DLC3010	16.96	18.32	20.49	14.98
DLC2020	16.39	17.69	20.45	13.20
LLC200 – DLC3010	**-4.42**	**-7.75**	**-3.38**	**-5.98**
LLC200 – DLC2020	**-3.85**	**-7.72**	**-3.34**	**-4.20**

Note: This table reports the distribution of RWR for different investment strategies by using historical simulation method. Mean, median, 25th percentile and 75th percentile are reported respectively. Specifically, Panel A reports the comparison results of leveraged life cycle and lifestyle strategies. Panel B reports the comparison results of leveraged life cycle and conventional life cycle strategies. Panel C reports the comparison results of leveraged and dynamic strategies. The details of each strategy are illustrated in Table 4.

Looking at leveraged asset allocation strategies alone, the aggressive LLC100 strategy generates highest and the conservative LLC200 generates the lowest mean, median, 75th percentile and 25th percentile results. This result indicates that the investor's portfolio value decreases as the borrowing costs increase. To be consistent with the discussion of results and for comparison purpose, the conservative leveraged life cycle strategy (LLC200) is examined in more detail.

The results in Panel A show that RWRs vary significantly across different asset allocation strategies. The 100 stocks strategy generates RWRs higher than the other strategies, and the 100 bonds strategy generates the lowest RWRs. These results show that portfolio value increases with a higher stocks allocation. The results of comparing the baseline LLC200 leveraged life cycle strategy with the balanced strategy, demonstrate that the leveraged life cycle strategy outperforms the balanced strategy. For example, the LLC200 strategy in Panel A generates a median final RWR of 10.57 that is 0.75 higher than the corresponding balanced strategy. The differences of 75th and 25th percentile RWRs between the leveraged life cycle strategy and the balanced strategies grow even wider than those median results. The 75th percentile RWR of LLC200 is 2.58 higher than the corresponding balanced strategy. Panel B shows the simulation results of the leveraged life cycle and conventional life cycle strategies. The results show that the LLC200 strategy underperforms the corresponding LC90 strategy and LC95 strategy in most parameters. For instance, the LLC200 strategy generates lower (2.19 and 0.75) median RWRs than the corresponding LC90 and LC95 respectively. The only one exception occurs: when comparing 75th percentile estimates, the LLC200 strategy generates a higher (0.48) RWR than that of the LC95 strategy. Although differences between the conventional life cycle and leveraged life cycle strategies are relatively small, the results still indicate that the leveraged life cycle strategy underperforms conventional life cycle strategies. Results in Panel C are more prominent. The results of comparing the leveraged life cycle with dynamic life cycle strategies, indicate that the leveraged life cycle strategy is completely outperformed by the dynamic life cycle strategies. For instance, the LLC strategy generates lower (7.75 and 7.72) RWRs than corresponding DLC3010 and DLC2020 respectively. The comparative results between leveraged life cycle and dynamic life cycle strategy are relatively larger, with the smallest difference of RWR between the LLC200 strategy and DLC2020 when comparing 75th percentile estimates.

As higher volatility of stock returns can result in substantial losses for investors in later plan years due to the portfolio size effect (Basu and Drew, 2009), it is necessary to assess the riskiness of leveraged life cycle strategies and their competing strategies. One possible approach is to measure the tail risk, or the adverse wealth outcomes. A popular measure of tail risk used by academics and practitioners is value at risk (VaR). The concept of VaR is simple and straightforward in that losses greater than VaR are suffered only in extreme circumstances. In other words, if an asset allocation strategy is less risky, it may generate better VaR outcomes. This study compares VaR at different probability levels to illustrate the relative riskiness of different asset allocation strategies. However, VaR is not without shortcomings as a risk measure. VaR specifies the amount at risk at a particular probability level, though it tells nothing about the potential exposure to losses for outcomes that are worse than VaR (Balzer, 1994). On the other hand, expected shortfall (ES) is considered to be a better candidate for risk measurement since it overcomes the limitation of VaR. ES is actually the probability weighted average of tail losses (Dowd, 2005). Therefore, we incorporate ES in this study as well.

Table 6 reports the estimates for VaR at 99 per cent, 95 per cent, and 90 per cent confidence levels, as well as ES at 95 per cent confidence level. The results indicate that the leveraged life cycle strategy outperforms the balanced strategy (Panel A); it underperforms the conventional and dynamic life cycle strategies (Panels B & C) with one exception: that leveraged life cycle strategies generate better results than dynamic life cycle strategy in the estimates of VaR at 99 per cent confidence level. When we consider the average for all outcomes below 95 per cent VaR estimates, the conventional life cycle strategies produce the highest results, followed in order by the leveraged life cycle strategies, dynamic life cycle strategies, and the balanced strategy generates the small ES estimate. These results suggest that plan investors concerned about the protection from extreme downside risk should select conventional life cycle strategies rather than other strategies.

Table 6: Value at Risk (VaR) and Expected Shortfall (ES) Estimates for Different Investment Strategies

Investment strategy	VaR at different confidence levels			ES at 95% confidence level
	99%	95%	90%	
PANEL A (leveraged life cycle versus lifestyle investment strategies)				
LLC100	5.29	6.12	6.72	5.50
LLC200	5.18	6.00	6.59	5.39
100 Stocks	4.80	6.04	7.60	5.17
100 Bonds	2.38	2.57	2.74	2.41
Balanced	5.03	5.78	6.20	2.56
LLC200 -- Balanced	**0.15**	**0.22**	**0.39**	**2.83**
PANEL B (leveraged life cycle versus life cycle investment strategies)				
LLC100	5.29	6.12	6.72	5.50
LLC200	5.18	6.00	6.59	5.39
LC90	5.55	6.14	6.52	5.78
LC95	5.36	6.16	6.65	5.6
LLC200 – LC90	**-0.37**	**-0.14**	**-0.07**	**-0.39**
LLC200 – LC95	**-0.18**	**-0.16**	**-0.06**	**-0.21**
PANEL C (leveraged life cycle versus dynamic life cycle investment strategies)				
LLC100	5.29	6.12	6.72	5.50
LLC200	5.18	6.00	6.59	5.39
DLC3010	4.80	6.04	7.60	5.17
DLC2020	4.80	6.23	7.78	5.21
LLC200 – DLC3010	**0.38**	**-0.04**	**-1.01**	**0.22**
LLC200 – DLC2020	**0.38**	**-0.23**	**-1.19**	**0.18**

Note: This table reports the VaR and ES estimates of RWRs for different investment strategies by using historical simulation method. VaR at 99%, 95% 90% confidence levels, and ES at 95% confidence level are reported respectively. Specifically, Panel A compares the VaR and ES leveraged life cycle and lifestyle strategies; Panel B compares the VaR and ES of leveraged life cycle and conventional life cycle strategies; Panel C compares the VaR and ES of leveraged life cycle and dynamic life cycle strategies. The details of each strategy are illustrated in Table 4.

In order to confirm these findings, we explore the distribution of RWRs and estimates of VaR and ES by using an alternative bootstrap simulation method, as illustrated in Table 7 for the wealth accumulation distribution of RWRs for different asset allocation strategies by using this method. The comparative results for different asset allocation strategies are generally consistent with the results in Table 5. These results demonstrate that the leveraged life cycle strategy outperforms the corresponding balanced strategy, and significantly underperforms the corresponding dynamic life cycle strategies, while the comparison of the leverage life cycle strategy with the conventional life cycle strategies, gives mixed evidence. For instance, the LLC200 strategy underperforms the LC90 strategy at the median and 75th percentile, but outperforms the LC90 strategy at the 25th percentile (0.06). The LLC200 strategy underperforms the LC95 strategy at the 75th percentile, but outperforms the LC95 strategy at the median and 25th percentile. The differences between leveraged life cycle and conventional life cycle strategy are all relatively small. Such mixed evidence may indicate that the leveraged life cycle strategy demonstrates a similar characteristic as the conventional life cycle strategies.

Table 7: Distribution Parameters of Retirement Wealth Ratio (RWR)

Investment strategy	Mean	Median	75th Percentile	25th Percentile
PANEL A (leveraged life cycle versus lifestyle investment strategies)				
LLC100	12.41	10.50	15.38	7.16
LLC200	12.22	10.31	15.11	7.09
100 Stocks	19.70	13.02	23.52	7.35
100 Bonds	4.86	4.53	5.62	3.74
Balanced	10.81	9.29	13.28	6.65
LLC200 - Balanced	**1.41**	**1.02**	**1.83**	**0.44**

Table 7: Distribution Parameters of Retirement Wealth Ratio (RWR) (continued)

Investment strategy	Mean	Median	75th Percentile	25th Percentile
PANEL B (leveraged life cycle versus life cycle investment strategies)				
LLC100	12.41	10.50	15.38	7.16
LLC200	12.22	10.31	15.11	7.09
LC90	13.61	10.69	16.68	7.03
LC95	12.71	10.28	15.62	6.96
LLC200 – LC90	**-1.39**	**-0.38**	**-1.57**	**0.06**
LLC200 – LC95	**-0.49**	**0.03**	**-0.51**	**0.13**
PANEL C (leveraged life cycle versus dynamic life cycle investment strategies)				
LLC100	12.41	10.50	15.38	7.16
LLC200	12.22	10.31	15.11	7.09
DLC3010	18.31	13.23	22.69	7.54
DLC2020	15.91	13.20	20.18	7.73
LLC200 – DLC3010	**-6.09**	**-2.92**	**-7.58**	**-0.45**
LLC200 – DLC2020	**-3.69**	**-2.89**	**-5.07**	**-0.64**

Note: This table reports the distribution of RWRs for different investment strategies by using bootstrap simulation method. Mean, median, 25th percentile and 75th percentile are reported respectively. Specifically, Panel A reports the comparison results of leveraged life cycle and lifestyle strategies. Panel B reports the comparison results of leveraged life cycle and conventional life cycle strategies. Panel C reports the comparison results of leveraged and dynamic strategies. The details of each strategy are illustrated in Table 4.

Next, we turn our attention to risk measures. Table 8 reports the estimates for VaR at 99 per cent, 95 per cent and 90 per cent confidence levels, as well as ES at 95 per cent confidence level in the bootstrap simulation method. These results are significantly different from Table 7. In all comparative results, the leveraged life cycle strategies outperform balanced, conventional life cycle, and dynamic life cycle strategies in terms of VaR at three different confidence levels and ES at 95 per cent confidence level. One possible explanation is that leveraged life cycle strategy has more ability to reduce risk than other strategies. This is consistent with the findings of Ayres and Nalebuff (2013), that the leveraged life cycle strategy using leverage to buy stocks increases short-term risk but it reduces long-term risk by enabling individuals to achieve better diversification across time. However, it is important to note that the differences are all relatively small. Investors may consider that the risk is not large enough to negate other strategies, especially dynamic life cycle strategies that have a strong ability to generate much better retirement outcomes.

Table 8: Value at Risk (VaR) and Expected Shortfall (ES) Estimates for Different Investment Strategies

Investment strategy	**VaR at different confidence levels**			**ES at 95% confidence level**
	99%	**95%**	**90%**	
PANEL A (leveraged life cycle versus lifestyle investment strategies)				
LLC100	3.03	4.28	5.16	3.52
LLC200	2.98	4.28	5.19	3.50
100 Stocks	2.02	3.36	4.50	2.53
100 Bonds	2.44	2.87	3.16	2.60
Balanced	2.94	4.01	4.85	3.35
LLC200 - Balanced	**0.04**	**0.27**	**0.34**	**0.15**
PANEL B (leveraged life cycle versus life cycle investment strategies)				
LLC100	3.03	4.28	5.16	3.52
LLC200	2.98	4.28	5.19	3.50
LC90	2.82	4.02	4.92	3.29
LC95	2.89	4.06	5.00	3.35
LLC200 – LC90	**0.16**	**0.26**	**0.27**	**0.21**
LLC200 – LC95	**0.09**	**0.22**	**0.19**	**0.15**
PANEL C (leveraged life cycle versus dynamic life cycle investment strategies)				
LLC100	3.03	4.28	5.16	3.52
LLC200	2.98	4.28	5.19	3.50
DLC3010	2.01	3.38	4.54	2.54
DLC2020	2.04	3.45	4.64	2.58
LLC200 – DLC3010	**0.97**	**0.90**	**0.65**	**0.96**
LLC200 – DLC2020	**0.94**	**0.83**	**0.55**	**0.92**

Note: This table reports the VaR and ES estimates of RWRs for different investment strategies by using bootstrap simulation method. VaR at 99%, 95% 90% confidence levels, and ES at 95% confidence level are reported respectively. Specifically, Panel A compares the VaR and ES leveraged life cycle and lifestyle strategies; Panel B compares the VaR and ES of leveraged life cycle and conventional life cycle strategies; Panel C compares the VaR and ES of leveraged life cycle and dynamic life cycle strategies.

Conclusion

This study investigates the relative performance of leveraged life cycle strategy and other investment strategies that are currently offed by DC plan providers, as well as those suggested in the literature. In particular, this study seeks to find whether leveraged life cycle strategy is able to produce better retirement outcomes than balanced, conventional life cycle and dynamic investment strategies for DC plan investors. Although, in reality, asset allocation strategies employed in the DC plan are more sophisticated than our prototypical asset allocation strategies represented in this study, the findings of our study at least cast some doubt on the relative performance of different investment strategies for DC plan investors.

Using the historical simulation method, we find that the leveraged life cycle strategy is able to produce better retirement outcomes than those of the balanced strategy, but it produces retirement outcomes inferior to the conventional life cycle and dynamic life cycle strategies. However, using the bootstrap simulation method, the results tell a slightly different story. These results suggest that the leveraged life cycle strategy demonstrates superiority over the balanced strategy and inferiority to the dynamic life cycle strategies, but it has a characteristic similar to conventional life cycle strategies in terms of RWR distributions. Further, the leveraged life cycle strategy shows more ability to reduce risk than other strategies.

The findings of this study have revealed several results. First, the leveraged life cycle strategy has the ability of risk reduction, which is consist with the findings of Ayres and Nalebuff (2013), though the risk reduction ability is relatively insignificant. Second, the leveraged life cycle strategy demonstrates a comparative advantage to the balanced strategy. In fact, balanced strategy shows inferiority to each strategy that has been examined, which may suggest that it is not an appropriate investment choice for DC plan investors. Third, the leveraged life cycle strategy demonstrates inferiority to conventional life cycle strategies in most cases. We attribute this result to the possibility that they may have similar risk-return characteristics, which is worth further investigation. In addition, compared to leveraged life cycle with dynamic life cycle strategies, the leveraged life cycle strategy demonstrates significant inferiority to dynamic life cycle strategies. Previously, some may have argued that leveraged life cycle strategies can be considered as superior investment strategies for DC plan investors as they show the ability of risk reduction. However, these risk reduction benefits may come at a substantial cost to the investors through giving up the significant upside potential of wealth (Basu, *et al.*, 2011; Hickman, *et al.*, 2001). Another interesting finding is that, as suggested by Basu, *et al.*, (2011), dynamic asset allocation strategies are able to produce much better retirement outcomes for investors. This may represent a superior alternative to the conventional deterministic life cycle strategy and is worthy of further investigation.

In terms of practical implications, the biggest challenge for leveraged life cycle strategies is how to convince investors to stay with the disciplined strategy during market downturns, such as in a situation where DC plan investors had 200 per cent of their savings in stock during the 2008-2009 crash. As the leveraged life cycle strategy demonstrates a relative risk reduction ability, it would be useful to investigate whether leveraged life cycle strategies have the real ability of risk reduction by using more risk measures. Nonetheless, this is an area of future research.

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