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Assessing the effectiveness of lifecycle (target-date) funds during the accumulation phase

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Abstract

Using bootstrap simulations, asset allocations that mimic real-world lifecycle fund behavior are shown to have lower accumulation efficiency than several available alternatives. The alternatives include fixed stock/bond allocation with 80% or more in stocks and a set of adaptive strategies that attempt to protect gains against catastrophic loss. It seems that during the accumulation phase, lifecycle funds are not as safe, reliable, or effective as implied. © 2011 Academy of Financial Services. All rights reserved.

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1. Introduction

Lifecycle (or alternatively, target-date) mutual funds change portfolio asset allocation on a schedule based on an investor's age, where age is used as a surrogate for the investor's place in the "lifecycle." Each investor can contribute to a lifecycle fund that matches his or her anticipated retirement year and the mutual fund does the rest. This is the mutual fund industry's version of "cruise control asset management." Israelsen (2008) estimated that at the end of 2007, 229 distinct lifecycle funds with $177.7 billion in assets were under management. According to the Investment Company Institute (2010) assets under manage-

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ment (AUM) reached $183 billion at the end of 2007 before declining to $160 billion by the end of 2008. The number increased to $256 billion again at the end of 2009. The popularity of such funds is expected to further increase, because Department of Labor rules have designated them as one of the three Qualified Default Investment Alternatives (QDIAs).

The focus of this investigation is on a subset of lifecycle funds, specifically those categorized with target retirement dates in the 2050–2055 range. Lifecycle funds tend to reallocate funds to higher and higher concentrations of bonds as one approaches retirement. Such rebalancing strategies may result in a much lower accumulated balance at the end of 40/45 years than portfolios that maintain 50% or more in stock throughout the four decades. The empirical question of interest is: "How effective are lifecycle accumulation schemes compared to some unmanaged constant allocation?"

2. Lifecycle funds: A synopsis

2.1. Literature review

Because lifecycle mutual funds are a relatively recent invention, the amount of research on them is limited. Nagengast, Bucci, and Coaker (2006) study the performance and structure of the retail lifecycle fund offerings of six major fund families. They rank the desirability of the funds based on a weighted score of six major parameters: structure/strategy, expenses, allocation, performance, and two measures of risk. They conclude that funds generally have performed in line with market returns.

Bodie and Trussard (2007) suggest integration of human capital risk in the optimization process. One of their conclusions is: "... People who are very risk averse and who have a high exposure to market risk through their labor income would experience a substantial gain in welfare from being offered a safe lifecycle fund rather than a risky one." (p. 47) They suggest that the transition from equities to debt in the lifecycle funds be less linear and more "humped."

Mitchell, Mottola, Utkus, and Yamaguchi (2007) study portfolio compositions before and after the existence of lifecycle funds. When lifecycle funds are available, the number of "all equity" or "all cash" portfolios in pension plans decreases. Lifecycle funds are found to change stock/bond allocations by age group (in part) probably because of the additional asset allocation opportunities provided in the lifecycle funds.

Schleef and Eisinger (2010) use a Monte Carlo in a multi-period setting to estimate the probability of reaching a target value at retirement. Compared with fixed allocation models, lifecycle funds that reduce equity exposure over time, are not more likely to reach a target value.

Spitzer and Singh (2008) use a bootstrap simulation to study the shortfall risk of target-date funds during the retirement years. They classify target-date funds into three types of glide paths: Steep, Gentle, and Fixed 25/75.[1] They show that all three glide path strategies have higher shortfall risk than a constant 50/50 allocation. They urge the designers of target-date mutual funds to "rethink their asset allocation during retirement." (p. 151)

Vicera (2009) examines lifecycle funds in the context of portfolio theory. One of his conclusions is that when the default choices (in a QDIA) for a defined contribution plan are between a target fund and a money market fund, the lifecycle fund is preferable. He also recommends designing target-date funds based on life expectancy and not on retirement dates.

Lauricella (2009) in the shadow of the 2008 recession, questions the wisdom of a cookie cutter asset allocation approach of lifecycle funds. He reports negative returns in the range of 7% to 46% for the lifecycle funds and an average loss of 29% in 2008 for such funds.

Liu et al. (2009) utilize bootstrap simulations to compare the accumulation performance of a prototype glide path to constant allocation portfolios with differing exposure to equities ranging from 100% to 50% for accumulation periods ranging from 10 to 40 years. They find that "Portfolios that follow a glidepath strategy (i.e., decreasing equity and increasing bond allocations) during retirement tend to have lower probabilities of sustainability than portfolios that maintain a constant stock:bond allocation." (p. 12)

In a new approach, Branch and Qui (2009) calculate the size of an annuity that can be purchased at the end of the accumulation period by various lifecycle fund strategies. They use a novel methodology in the bootstrap to capture the serial correlation of asset returns. They find

> the mean accumulations and annuity values rise monotonically with the percentage of the stock allocation and for the 50/50 and higher allocations favor the fixed over the target allocations. While the variability is greater for the fixed allocations, both the Sharpe and Treynor ratios are substantially higher for the high concentration stock portfolios than they are for the target portfolios. These results pose a major challenge to the claims that the target date funds are an effective retirement planning vehicle. (p. 1)

Pfau (2010) finds that target-date funds are a rational choice for some. Rather than attempting to maximize accumulated wealth, investors maximize a utility function. Pfau concludes that "savers with very reasonable amounts of risk aversion" (p. 73) attain higher utility from target-date funds than from amassing more wealth.

2.2. *Lifecycle fund diversity*

Individuals usually begin to contribute to a retirement plan or intend to do so soon when in the 25–35 age range. As of today, the lifecycle funds designated as "2050" to "2055" funds would be the appropriate funds for such individuals.

Table 1 provides information about several such "Target Date 2050" or "Target Date 2055" funds. For each fund family, the longest available target-date fund is used. (There are five 2045 funds at the end of Table 1, below the solid line. These fund families are not currently offering 2050 or 2055 target-date funds. When they do so, it is assumed that the future funds will strongly resemble the listed fund.) The starting allocation of stocks and bonds, the ending allocation of stocks and bonds, and the number of years it will take to get from the starting to the ending allocation (Time-to-Target) are noted in the table. For example, T. Rowe Price Retirement 2055 Fund begins with a 90/10 stock/bond allocation and retains this allocation until 20 years before retirement. Subsequently, the asset allocation

Table 1 Description of 2045 to 2055 lifecycle funds by fund family, starting allocation, ending allocation, and time-to-target

Fund family	Fund name	Ticker	Starting and ending stock/ bond allocation*	Time-to-target	Comments
Alliance Bernstein	All-Bern 2055 Retirement Strategy	LTWAX	95/5 65/35	45 years	Relatively unchanged allocation up to 25 years before retirement. Equity exposure continuously reduced during retirement.
American Century	LIVESTRONG 2050 Portfolio	ARFVX	80/20 45/55	40 years	Some managerial discretion on asset allocation permitted. Gradually reducing equity exposure.
American Funds	American Funds Target Date Ret 2050	AALTX	95/5 30/70	40 years	Constant allocation up to 20 years before retirement. Up to 20% of equity exposure may be invested in balanced funds.
Fidelity	Fidelity Freedom 2050 Fund	FFFHX	90 to 100/10 to 0 45 to 90/55 to 10	40 years	Relatively unchanged allocation up to 20 years before retirement. Retirement target reached two years around retirement date.
Goldman Sachs	Goldman Sachs Ret Strategy 2050	GRPAX	90/10 45/55	40 years	Gradually reducing equity exposure.
Hartford	Hartford Target Retirement 2050	HTPRX	95/5 60/40	40 years	Gradually reducing equity exposure
JP Morgan Chase	JP Morgan Smart Retirement 2050 Fund	JTSAX	None Provided	40 years	Discretionary asset allocation
Manning & Napier	Manning & Napier Target 2050	MTYCX	None Provided	40 years	Discretionary asset allocation
Mutual Fund Series	MFS Lifetime 2050	MFFSX	95/5 25/75	40 years	Relatively unchanged allocation up to 25 years before retirement, then monotonically decreasing retirement.
Principal	Principal Lifetime 2050 Fund	PPEAX	None Provided	40 years	Discretionary asset allocation
Putnam	Putnam Retirement Ready 2050 Fund	Not Available	95/5 25/75	40 years	Asset allocation adjusted every five years to reflect increasing conservatism.
State Farm	State Farm Lifepath 2050 Fund	NLPAX	None Provided	40 years	Barclays proprietary asset allocation model.
TIAA-CREF	Lifecycle 2050 Fund	TLFRX	90/10 50/50	40 years	Relatively unchanged allocation up to 20 years before retirement, then monotonically decreasing retirement. Allowed discretionary change of ±10%.

Table 1 (Continued)

Fund family	Fund name	Ticker	Starting and ending stock/bond allocation*	Time-to-target	Comments
T. Rowe Price	T. Rowe Price Retirement 2055 Fund	TRRNX	90/10 55/45	45 years	Relatively unchanged allocation up to 20 years before retirement, then monotonically decreasing into retirement.
Vanguard	Vanguard Target 2050 Fund	VFIFX	90/10 50/50	40 years	Relatively unchanged allocation up to 20 years before retirement, then monotonically decreasing into retirement.
Wells Fargo	Wells Fargo Advantage Dow Jones 2050 Fund	WFQGX	90 % of risk of the global equity market	40 years	Mimics allocations of the Dow Jones Target 2050 Indexes.
Columbia Funds	Columbia Retirement Plus 2045	RRPYX	95/5 70/30	35 years	Neutral allocation of 80% equities up to 15 years before retirement reducing to 50% by retirement date.
Franklin Templeton	Franklin Templeton 2045 Retire Target	Not Available	100/0 60/40	35 years	Constant allocation up to 30 years before retirement. Declining equity exposure until five years into retirement.
Guidestone	MyDestination 2045	GMFZX	100/0 40/60	35 years	Gradually reducing equity exposure.
John Hancock Funds	Lifecycle Retirement Portfolio 2045	JLJAX	100/0 50/50	35 years	Relatively unchanged allocation up to 25 years before retirement. Gradually reducing equity exposure after that.
Vantagepoint	Vantagepoint Milestone 2045 Fund	VPRJX	95/5 70/30	35 years	Constant allocation in the first five years, then monotonically decreasing into retirement. Constant allocation after 10 years into retirement.

*REITs are treated as stocks and included in the stock allocation. Cash equivalents are treated as Fixed Income securities and included in the bond allocation.

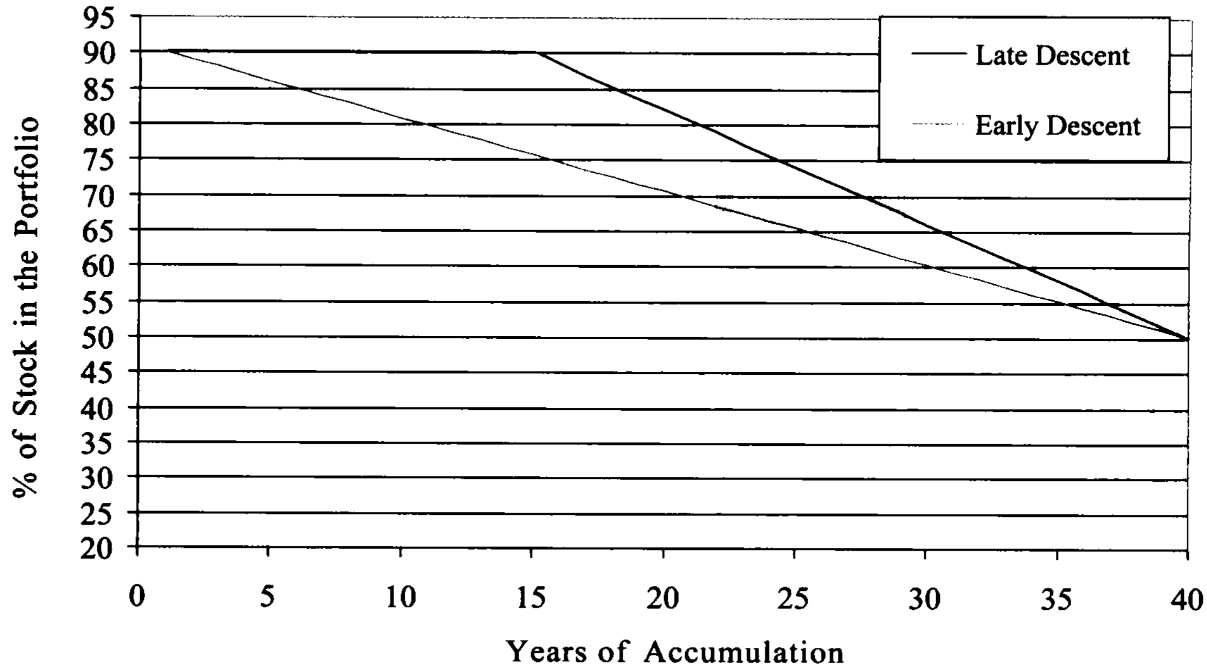


Fig. 1. Late descent and early descent lifecycle strategies.

to equities is systematically reduced until it attains a 55/45 stock/bond allocation. (Equity exposure will generally continue to be reduced in retirement for all such lifecycle funds. The emphasis here is on the accumulation phase, not the postretirement phase.) As a comparison, the American Century LIVESTRONG 2050 Portfolio begins with an 80/20 stock/bond allocation and immediately begins to reduce the ratio to the 45/55 stock/bond target allocation. Additional comments are added as necessary. For simplicity in exposition, cash equivalents and preferred stocks are categorized as fixed income assets and included in the bond portion. Because of their equity-like features of discretionary dividends and equity market trading, REITs are treated as equity securities and included in the stock allocation.

It is not the purpose of this article to compare one lifecycle fund to another, but rather to evaluate the performance of different lifecycle fund strategies. Two broad transparent asset allocation strategies can be culled from Table 1 and are illustrated in Fig. 1. The two strategies are composites or proxies for actual lifecycle funds. These are:

"*Late Descent*": The percentage of stocks stays constant at 90% for the first 15 years and then begins to fall over the next 25 years until it reaches 50%.
"*Early Descent*": Begin with 90% in equities, the percentage of stocks falls gradually to 50% over 40 years.

3. Models, data, and methods

In an earlier article, Spitzer and Singh (2008) compared the efficiency in target-date funds in the withdrawal phase during retirement. A similar methodology is used here with the focus on the accumulation phase.

Table 2 Asset allocation strategies used in the bootstrap simulations

Model number	Portfolio composition	Comment
1	100% cash	Represents one of the three QDIA default options
2	50% cash/50% stocks	Represents a combination of two QDIA default options
3	30% stocks/70% bonds	
4	40% stocks/60% bonds	
5	50% stocks/50% bonds	
6	60% stocks/40% bonds	
7	70% stocks/30% bonds	
8	80% stocks/20% bonds	
9	90% stocks/10% bonds	
10	100% stocks	Represents one of the three QDIA default options
11	Late descent	A lifecycle fund proxy
12	Early descent	A lifecycle fund proxy
13	100 jump	Experimental: 100% stock until portfolio balance gets to $100, then 50%
14	200 jump	Experimental: 100% stock until portfolio balance gets to $200, then 50%
15	300 jump	Experimental: 100% stock until portfolio balance gets to $300, then 50%

3.1. Models

Fifteen allocation strategies (models) are studied. Table 2 contains descriptions, and comments where pertinent. The first 10 of the allocation strategies have fixed allocations. Models 11 and 12 represent the lifecycle proxies from Fig. 1, while the last three are attempts at improving on the previous dozen.

Model 1 is 100% cash, represented by U.S. Treasury bills. This model corresponds to one of the three available QDIA options: a money market fund, a large-cap stock market fund, or a lifecycle fund. Model 2 is a composite of two QDIA choices with a 50/50 mixture of cash and stocks. Models 3 through 10 are fixed stock/bond allocations: Model 3 is 30% stocks, Model 4 is 40% stocks, . . . , Model 10 is 100% stocks. Model 10 also represents a QDIA default option. Model 11 is the lifecycle proxy designated as Late Descent (constant 90% stock allocation for the first 15 years), and Model 12 represents Early Descent.

Models 13 through 15 are simplistic attempts at refining outcomes; these models have the ability to adapt their behavior based on changing conditions. In light of portfolio losses experienced in 2008, future retirees wished that they could have "taken their winnings" and put them in a safe place. The idea behind Models 13 through 15 reflects that desire. None of these three adaptive models are intended as the best strategy, but merely a first naïve attempt in that direction. Here is how they work. In each instance, the portfolio maintains a 100% stock allocation until a target portfolio amount of $100, $200, or $300 is reached in Models 13, 14, and 15, respectively. In many instances, the target portfolio amount may never be achieved. When this happens, the model continues to hold 100% in stock. If the target is obtained, the asset allocation immediately "jumps" to a 50%/50% stock/bond allocation. The intent is to lock in the portfolio balance and protect it from dramatic down-side movements.

3.2. Data

Annual total returns from 1926 to 2008 for Large Company Stock, Intermediate-Term Government Bonds, and U.S. Treasury Bills are obtained from Ibbotson Associates (2009). The data are nominal returns; they have not been adjusted for inflation.

3.3. Methods

Our research question now is "Which model(s) can reliably amass the largest portfolio at the end of 40 years?" Starting with a zero balance, $1 is added to each portfolio at the beginning of every year.[2] A "year" between 1926 and 2008 (inclusive) is randomly selected and the rates of return on stocks, bonds, and cash from that year are used to calculate the new portfolio balance based on the asset allocation rules in effect for each model. Rebalancing of the portfolio is implicit. For example, Model 5 is specified to be 50/50 in stocks and bonds. Let P(t) be the value of the portfolio at the start of the t-th year. Let the (randomly selected) rates of return on stocks, bonds, and cash for the year be R_s R_b and R_c respectively. The value of Model 5's portfolio at end of the t-th year is then calculated to be $P(t)(1+0.5*R_s + 0.5*R_b + 0.0*R_c)$. An additional dollar will be added to this calculation to represent the portfolio value at the start of the next year.[3] The size of the portfolio will fluctuate over time as rates of return vary and as additional contributions are added. For each of the fifteen options, 10,000 40 year sequences of accumulations are performed. The 10,000 ending balances for the 15 models are saved for further analysis. The distribution of (terminal) portfolio balances provides useful information on portfolio means, medians, ranges, standard deviations, and shapes. It is of special note that each of the portfolios is exposed to precisely the same rates of return on stocks, bonds, and cash in exactly the same order. Differences among the portfolio distributions are therefore attributable to asset allocation difference, not the stochastic returns themselves. The appendix provides a more complete algorithm for the bootstrap.

4. Results

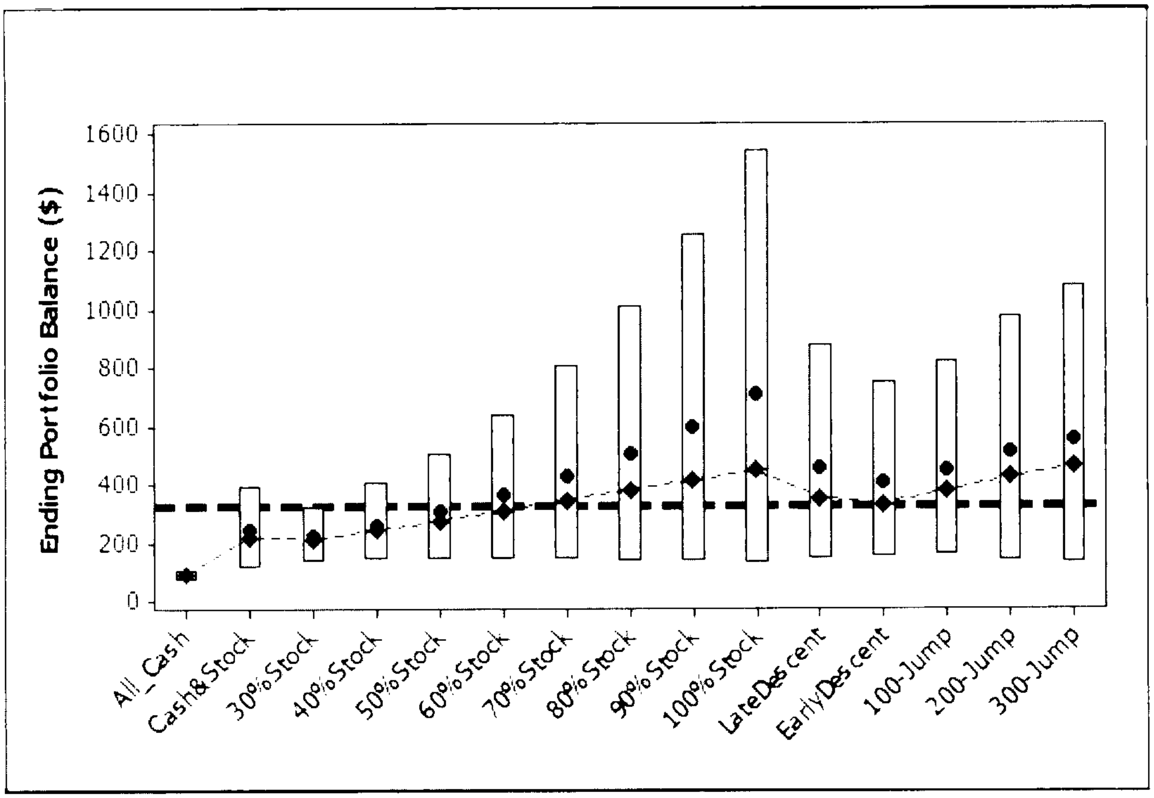
The amount of summary data is considerable. In the spirit of parsimony, only three summary "views" of the data are provided. The first is a table of statistics, the second a graphical depiction of the shapes of the distributions, and the last is a glimpse at the relative likelihood of attaining a specific portfolio goal.

Table 3 provides raw statistics – mean, median, standard deviation, minimum, and maximum for the ending portfolio size of all models. The reader may use these numbers in their current form, or may reference them in relationship to Fig. 2, which will be discussed below. It is clear from these summary data that the "all cash" option of Model 1 has the least variation and also the smallest mean and median accumulation of money. Models 3 through 10 (fixed stock/bond percentages) show a clear pattern of rising mean and median balance as the stock percentage increases. As expected the dispersion increases with the stock percentage as well. Model 2, the composite cash/stock model, performs similarly to Model

Table 3 Various statistics for ending portfolio balances for selected accumulation strategies after 40 years based on 10,000 iterations

	Model number and description														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Cash only	Cash/ stocks	30% stock	40% stock	50% stock	60% stock	70% stock	80% stock	90% stock	100% stock	Late decent	Early descent	100- jump	200- Jump	300- jump
	Statistic values in dollars*														
Mean	90	242	223	262	308	363	429	506	598	707	453	405	445	510	552
Median	89	219	212	242	275	310	346	380	414	447	353	331	378	424	460
SD	11	117	74	108	156	223	315	441	613	847	358	281	292	364	417
Minimum	59	44	65	58	50	41	34	28	22	18	38	42	18	18	18
Maximum	151	1,133	677	999	1,527	2,515	4,117	6,697	10,811	17,313	4,924	3,580	3,285	3,783	4,407

*$0 starting value in all models with $1 added at the start of each year.



• - Designates the location of the mean. ♦ - Designates the location of the median. The rectangle shows the middle 80% of the Distribution of Ending Balances.

Fig. 2. Boxplots of ending portfolio balances after 40 years for selected accumulation strategies.

3 (30% stocks, 70% bonds), having a slightly higher mean, median, and standard deviation. Model 2 performs poorly compared with any of the remaining models, but better than Model 1 (100% cash). The lifecycle proxies, Models 11 and 12, have higher means and medians than Models 3, 4, 5, 6, or 7, but models with 80% or more stock (Models 8 through 10) have larger means and medians than the lifecycle funds do. The lifecycle funds could be forgiven their inferior performance if they offered significantly superior down-side protection, but, as will be illustrated below, they do not. Models 8 through 10 offer higher mean and medians compared with either of the lifecycle fund proxies. Models 13 through 15 (the jump to 50% models) have larger median balance remaining than the lifecycle proxies. Model 13 has larger mean and median and smaller standard deviation than Model 7 (70% stock). Models 14 and 15 perform similarly to Model 8 (80% stock).

Fig. 2 is a series of boxplots that allow easier relative comparisons among the various models. Several aspects of each models' statistical personality are shown in the 15 rectangles. The y-axis shows the ending balance scale. The diamond-shaped character in each rectangle designates the location of the median balance, and the circle shows the mean balance. All models exhibit right-skewness (the mean exceeds the median) and the distance between the mean and median increases as the amount of stock increases. The rectangle itself represents the middle 80% of the distribution of ending balances. Consequently, 10% of the ending balances in each Model will be larger than the top of the rectangle, and 10% will be

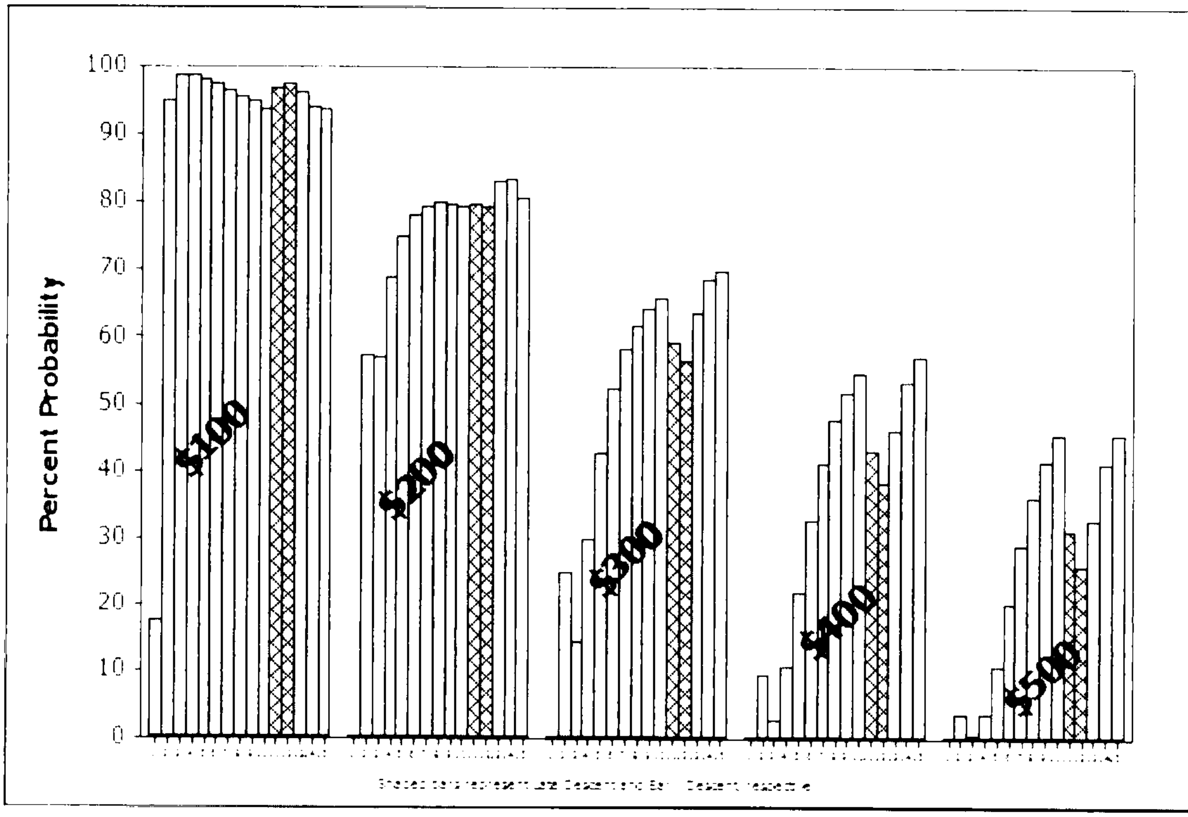


Fig. 3. Probability of having a $100, $200, $300, $400, or $500 ending portfolio balance after 40 years for selected accumulation strategies.

smaller than the bottom. The median and mean balance both increase as the stock percentage in the portfolio increases. Model 1, the all cash portfolio, has extremely poor performance compared with all other options. Model 2, the mixture of stocks and cash does about as well as the 30% stock portfolio, Model 3. As one would expect, Model 10, 100% stock, has the largest mean and the largest variance. There is a dashed horizontal line at $331 at the median for Model 12, Early Descent. Using this reference line, it is easily seen that Model 12 performs on a par with Model 7 on the basis of median, but has a smaller mean. Neither lifecycle model performs as well as Models 8, 9, 10, 13, 14, or 15 as measured by the median. Based on Fig. 2, the lifecycle models do not offer superior down-side protection, have mediocre median performance, and limit potential maxima.

The last perspective is offered in Fig. 3, where the probability of achieving a specific portfolio goal is shown. There are 5 clusters in the figure. Cluster 1 shows the probabilities in each of the 15 models of attaining at least a $100 ending balance. Clusters 2 through 5 show the probabilities in each of the 15 models of attaining at least a $200, $300, $400, and $500 balance, respectively. The two cross-hatched rectangles are the lifecycle proxies of Models 11 and 12. In Cluster 1, all models except Model 1 are likely to attain at least a $100 ending balance with probability exceeding 93%. Model 1 attains a $100 ending balance only about 17% of the time.

As the ending balance size increases, the probability of success decreases, in some instances very rapidly. For example, for Model 5 (50/50 Stocks/bonds) the probability of attaining a $100 balance is 98%, but drops to 75% at $200, 43% at $300, 22% at $400, and 11% at $500. Although not apparent on the graph, Model 1 all but disappears for ending balances greater than $100!

The lifecycle models do about the same as Models 3, 4, and 5 in attaining a minimum $100 ending portfolio. These models slightly out-perform Models 7 through 10 by 1–3%. The advantage is short-lived however. The probability of attaining ending balances of $200, $300, $400, and $500 falls faster for the lifecycle models than for either the jump models or for constant allocation Models 8, 9, and 10. All of the jump models are more likely to surpass the lifecycle models for the $200 Cluster and all higher clusters shown. Models 8 through 10 perform equivalently to the lifecycle models at $200, but begin to outperform them at higher ending balance targets. For ending balance amounts of $600 or more (not shown), Model 10 (100% stocks) pulls away from the pack as the clear victor. One can refer back to Table 3 and observe the size of the maximum balance achieved by Model 10. These unlikely results will eventually ensure that Model 10 is capable of attaining a large ending balance that no other model can approach, though with accompanying volatility.

5. Summary and conclusion

Lifecycle (or target-date) funds are a relatively new tool with which retirement savings may be amassed. Sellers of such funds provide systematic rebalancing of a retirement portfolio to which the employee (and often the employer) makes regular contributions. Typically, the stock portion of the lifecycle portfolio diminishes over time so that the portfolio becomes increasingly conservative as the owner nears the (target) retirement date. Fifteen different asset allocation strategies (models), including two lifecycle examples, are evaluated in a bootstrap simulation to see which models reliably attain the largest ending balance at the end of 40 years. Eight of the models have fixed stock/bond percentages, two models contain cash in lieu of bonds, and three models use an adaptive strategy where the allocation rules change when a predetermined goal has been reached.

Many results echo those found elsewhere. These findings confirm those in Vicera (2009), that lifecycle funds are a better choice than an all cash portfolio. Branch and Qui's (2009) findings that the average ending balance increases monotonically with the proportion of stock are also confirmed. In contrast to Branch and Qui, present results do not confirm that fixed portfolios of 50%, 60%, or 70% stocks are better than the lifecycle funds. Only fixed portfolios of 80% or more stocks are found here to outperform lifecycle funds. When measuring the likelihood that a particular model will achieve a specific goal (100, 200, 300, 400, or 500 times the annual contribution size), the lifecycle funds performed well for the smallest goal; both variants of lifecycle funds attained the smallest goal about 96% of the time. However, portfolios of 80% or more stock begin to equal and then exceed the lifecycle fund performance as the ending balance goal goes beyond 100.

Three adaptive models proved to be surprisingly effective. Except for the smallest goal, all of the adaptive models had a higher probability of attaining a specific ending balance amount than the lifecycle funds or any of the fixed allocation funds.

Spitzer and Singh (2008) found the performance of target-date funds during the withdrawal phase (i.e., during retirement) to be inferior to alternative fixed allocations. The present study strongly suggests that lifecycle funds are inferior during the accumulation period as well. Employees are likely to amass more money by their retirement date by either investing in fixed proportion portfolios with at least 80% stock (the more the better!) or by implementing some adaptive strategy along the lines suggested here.

The results also have some policy implications for regulators. In light of its very poor outcome, the all cash default option (Model 1) for QDIAs needs revisiting. Like target-date portfolios, automatically rebalanced portfolios with predefined stock allocations might also be considered for "safe haven" status. Model 2 (50% cash and 50% equity), for example, when annually rebalanced, could provide a transparent and cost-effective option for the fourth QDIA.

Notes

1. Steep and Gentle are initially set at 50% stock/50% bonds at the start of retirement and fall to 25% stock/75% bonds either rapidly (Steep) or slowly (Gentle) during retirement. Fixed 25/75 is fixed at 25% stock/75% bonds throughout the withdrawal years.
2. This study seeks to discover which models are likely to reliably attain large ending balances, in nominal terms. The constant $1 annual contribution is problematic, since in real life such things as salary increases, bonuses, and increases in contribution limits, imply that contribution amounts will likely grow over time. The idea of a constant annual increase in the contribution amount was rejected on grounds that it is unrealistic. Promotions and contribution limits change sporadically, not regularly. In an attempt to mirror this behavior, a second set of bootstraps was done, where the contribution was increased by 10% after every 5 years – a series of steps or jumps rather than a smooth increase. Thus in year 6, the annual contribution was $1.10, in year 11 it increased again to $1.21, etc. The second set of estimates had larger ending balances, of course, but the relative differences among the 15 models did not change. The constant $1 contribution seems adequate to capture the differences among models.
3. The $1 contribution amount has an interesting benefit: it is scalable. Real-world individuals may have vastly different annual contribution amounts. Those in 401(k) plans may contribute the (current) maximum of $16,500 each year. Alternately, those in an IRA may contribute their maximum of $5,000. Others may contribute only what they can comfortably afford, well below the limit. The scalability of the ending balances means that multiplying any balance statistic in this study by the actual annual contribution amount obtains a reasonable estimate of the statistic in a real context. For example, if the median ending balance for a portfolio in Model X (any of the 15 models) is $100, this corresponds to a $500,000 median balance for a person who contributes $5,000 per year. If a mean balance for Model Y is $500, then the corresponding mean balance for a $5,000 per year contributor would be $2.5M.

Appendix: Bootstrap algorithm

Let:

$B_{m,t}$ = the portfolio balance of the m-th model at the beginning of the t-th year; W = \$1 the annual contribution; $\lambda_s, \lambda_b, \lambda_c$ = the proportion of stocks, bonds, and cash respectively specified by the allocation rule for the m-th portfolio; $R_{s,t}$, $R_{b,t}$, $R_{c,t}$ = Rates of return on stocks, bonds, and cash in the t-th year.

(No model holds all three assets. Only Models 1 and 2 contain Cash. Asset proportions are not constant for Models 11 through 15.)

The value of $b_{m,t}$ at the *end* of the t-th year is calculated as:

$$B_{m,t}\,[1 + \lambda_s R_{s,t} + \lambda_b R_{b,t} + \lambda_c R_{c,t}]. \tag{A1}$$

The value of the portfolio at the beginning of the next year will contain an additional annual contribution, *W*, hence,

$$B_{m,t+1} = B_{m,t}\,[1 + \lambda_s R_{s,t} + \lambda_b R_{b,t} + \lambda_c R_{c,t}] + W. \tag{A2}$$

Models 11 through 15 will have changing values of the λs over time.

For each iteration:

a. Set b_m = \$1, W = \$1. set a "year" counter to 0.
b. Using a uniform random number generator, generate a random number between 1926 and 2008 (inclusive) to represent the "year." Obtain the rates of return on stocks, bonds, and cash for this randomly selected year from the historical data.
c. Calculate the appreciated value of each portfolio using Eqs. A1 and A2.
d. Increment the "year" counter. If the year counter = 40, store the ending balance amounts for all the models for later analysis, otherwise, return to step b.

The above steps describe a single iteration of 40 years of accumulation. This process is repeated 10,000 times. When completed, there will be 10,000 ending balance amounts for each of the 15 models.

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