Working Paper

Asset Allocations and Risk-Return Tradeoffs of Target-Date Funds

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Abstract

This stochastic simulation analysis examines the risk characteristics of target-date funds focusing on the trade-offs between wealth creation and security. The dynamic portfolio adjustment of marketed target-date funds, with varied asset allocations, along age and various time horizons is shown. The probability distributions of account balances are produced using a vector autoregression simulation model of asset returns with the overlay of rare catastrophic financial and economic events. The risk-return tradeoffs associated with equity exposure, particularly for workers approaching retirement, underscore the importance of full disclosure, realistic assessment of risk tolerance and participant behavior, and due consideration of income strategies at and during retirement.

Key words: target-date fund, asset allocation, retirement accounts

JEL classifications: G11, G23, D14, D81

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I. Introduction

Target-date funds (TDFs), also known as life-cycle funds, have gained popularity among 401(k) plan participants and other investors saving for retirement. Adjusting the equity share automatically by the age of the investor, a TDF offers a simple way to combine stocks and fixed-income securities into a single dynamic fund, recognizing the typical path of human capital (earnings) prospects. For most defined contribution (DC) plan sponsors and participants, however, questions remain about the appropriate entry portfolios, the speed and nature of portfolio adjustment along the life cycle, and exit strategies at and during retirement. As has been evidenced by the recent financial crisis, TDF investors may face significant investment losses, depending on market exposures.

The Pension Protection Act of 2006 created new safe harbors for employers to adopt certain automatic enrollment arrangements in DC plans, especially 401(k)s, for eligible employees. The Department of Labor's regulations on "qualified default investment alternatives (QDIAs)," which feature TDFs, essentially mandate holdings of equities rather than money market and stable value funds as default investments for plan participants. Many plan sponsors had used the latter in the past. The plan fiduciary is relieved of some liability when a QDIA is implemented if the participant fails to make investment elections. Because it is believed by some that the possibility of investment losses was not well communicated to TDF investors and that the actual large losses in 2008 and early 2009 have been particularly harmful to those approaching retirement, TDFs are now also attracting heightened congressional and regulatory attention.[1]

This analysis examines, via stochastic simulation, the risk-return characteristics of TDFs actually marketed, with varied asset allocations, focusing on the trade-offs between wealth creation and security. We consider long-horizon investors who select or default into TDFs early in their career and also older workers who start utilizing TDFs just years before retirement. The stochastic simulation model produces probability distributions of final wealth balances of five stylized TDFs whose allocations represent the spectrum of equity exposure. The model allocations are based on market data of equity-bond-cash allocations, at various horizons, of tens of TDFs. For retirees, we further consider and compare income strategies, specifically two types of systematic withdrawals and purchases of fixed payout life annuities from TDF balances.

II. Asset Allocations in Target-Date Funds

A target-date fund holds a diversified mix of stocks, bonds and other assets. As the investor approaches retirement (the preset target date), the fund automatically shifts the asset mix away from stocks toward fixed-income securities. TDFs have mushroomed in recent years, with their assets increasing from $5.5 billion in 2000, to over $150 billion in 2007, and to over $204 billion by May 2008.[2]

[1] The Department of Labor and the Securities and Exchange Commission held a day-long hearing on TDFs on June 18, 2009 with almost 40 testimonies.
[2] Poterba et al. (2006), TIAA-CREF (2007), and Young (2008).

Consideration for "human capital" lends support to the idea that the equity share of retirement wealth accumulations should generally start high and then decline with age. Human capital, regarded as the present value of future wages, is thought by many analysts to carry less risk than equity and is more comparable to a bond. For most risk tolerances, larger equity holdings at a younger age appropriately complement the large human capital bond, whereas smaller equity and larger fixed-income holdings at an older age complement the declining value of human capital.[3]

Parenthetically, we note that the empirical evidence seems to show that the portfolios of retirement accounts held by individual workers differ significantly from this theoretical optimum. Table 1 reports the equity allocations by age of household head, based on the 2007 Survey of Consumer Finances. For all age bands, a significant number of households place their portfolios at the extremes – either nothing or all in equity. Roughly one third of investors hold 75+ percent of their account balances in equity. There is no clear tendency that investors start with a high equity exposure in their 20s or 30s and shift to bonds when they get close to retirement. Inertia may play a part as plan participants rarely reallocate their account balances. The portfolio line-ups and the automatic asset reallocation of TDFs are intended to help these investors improve their wealth creation and management, particularly along the age dimension.

[Table 1 here]

For most 401(k) plan sponsors and participants, questions remain about the appropriate entry portfolios, the speed and nature of portfolio adjustment along the life cycle, and exit positions upon retirement. In principle, the choices hinge on participants' risk preferences, the extent of defined benefit pension and Social Security coverage, the stability of their earnings, liquidity needs, personal characteristics, their planned retirement year, and other relevant factors. In practice, it is difficult to pinpoint all the factors and quantify them into a formula. In the marketplace, there is substantial variation in asset allocations among TDFs. When 401(k) plan participants select or default into different TDFs, their wealth profiles may differ significantly at retirement.

We first consider long-horizon investors who start utilizing TDFs in their early career. Figure 1 plots the glide paths of five TDFs, which are respectively at the 95th, 75th, 50th, 25th, and 5th percentiles, by equity share, of tens of 2050 TDFs on the market as of May 31, 2009. Because these TDFs are targeted for young workers who expect a long flow of bond-like labor earnings before retirement, all of them offer high equity position upon entry, ranging from 85 percent to 95 percent. Over the investment horizon of 40 years, portfolios in these fund families, which we designate TDF1E through TDF5E, are being shifted to bonds and cash. The variation of ending equity positions is even greater, from 35 percent to 60 percent, and there are cross-overs in equity shares along the way for these fund families.

[Figure 1 here]

[3] See discussions by Bodie et al. (1992) and Viceira et al. (2008), for instance.

Some workers may enter TDFs at the middle of their career. This situation may emerge, for example, when workers reallocate their investment portfolios within a 401(k) plan or when workers re-invest their retirement plan wealth upon job change. Figure 2 plots five TDFs (at the same percentiles of equity exposure in the initial allocations) that are targeted to mid-career workers who are likely to retire in 15 years. These TDFs commonly place initially 70 to 80 percent of assets in equity, but TDF1M has over 90 percent of assets in equity. Workers following glide paths of these respective fund families will have 35 to 70 percent of their wealth in equity at retirement.

[Figure 2 here]

We also consider older workers who start utilizing TDFs just a few years before retirement. As shown in Figure 3, there remains substantial variation in equity exposure. The equity share ranges from 40 to 80 percent five years before retirement, shifting to a range of 30 to 70 percent upon retirement. The potential risk-return tradeoffs associated with these TDFs are worth particular attention because workers at this stage may have limited time to make up large investment losses, depending on their overall financial and employment situation and their post-retirement income strategies.

For a comparison of income strategies for retirees (discussed later), we also collect the data on asset allocations in the respective final retirement income funds. When an income fund does not exist for a TDF family, we select the fund with an investment objective or style that is closest to that of an income fund. For simplicity, we assume that the portfolio transition to an income fund is instantaneous at the point of retirement and that asset allocations are constant thereafter from age 66 onward. These assumptions are largely in line with practice, though a few income funds continue to reduce their equity exposure through years in retirement.

Depending on the strategy used to generate income flows supporting the living standard in retirement, the allocations among fixed-income instruments can play a particularly important role for retirees. This is because bonds can be part of the hedging strategy against fluctuations in annuity purchase prices which owe to changes in market interest rates. As shown in Figure 3, some TDFs shift heavily to bonds while others move to cash in the transition into retirement, which will importantly affect the level and volatility of flows from various income strategies.

[Figure 3 here]

III. Simulations of Investment Returns with Normal Shocks and Rare Disasters

We simulate the range of investment outcomes according to TDFs' equity-bond-cash allocations, based on a stochastic model which allows for both standard market shocks in normal times and low-probability large-magnitude rare economic disasters. Expected returns on assets decrease with increased likelihood of a disaster. Negative skewness ("fat tails") is thus featured in the distribution of asset returns.

The dynamics of rates and returns in normal times are modeled as a vector autoregressive (VAR) system, following Campbell and Viceira (2004, 2005). This approach captures the serial correlations of variables and the contemporaneous correlations of market shocks. It also reflects the persistent shifts in risks and expected returns over long periods of time and the differing correlations of asset returns over short versus long horizons. The VAR coefficients and variance-covariance matrix, econometrically estimated on historical data, are embedded in the simulations to generate a large number of multiple-year series of rates and returns.

Equity, bond and cash are proxied by the S&P500 Total Return Index, the 5-year Government Bonds Total Return Index and 90-day Treasury bills, respectively. The returns are in real terms after adjusting for realized inflation, which is measured by the change in the CPI-U index. Additionally, three state variables in the VAR, which help form expectations of future rates and returns, include the short-term nominal interest rate (nominal T-bills), the equity dividend yield, and the slope of the yield curve (yield spread as the difference between US 5-year T-note zero-coupon yield and the yield on 90-day T-bills). For the simulations of annuity purchase prices (discussed later), the underlying discount rates are proxied by the yields on 5-year T-note zero-coupon bonds. The estimates are based on the 1962-2008 quarterly data.

Occurrences of rare economic disasters and corresponding value losses are simulated based on the framework of Barro (2006), who demonstrates that the possibility of rare disasters can explain the equity premium puzzle and "risk-free" interest rate behavior that are not well explained by conventional models. When disasters strike, equity contraction, government bond default and cash rate drop may occur with certain probabilities and by varying degrees. These probabilities and value shrinkages in Barro (2006) are estimated on 60 economic events (15+ percent declines in real per capita GDP during World War I & II, Great Depression, post-war depressions, etc.) in the twentieth century in 20 OECD, 8 Latin American and 7 Asian countries.

Value losses in disasters are applied to money market, stocks, and bonds. Impacts of these disasters carry forward in the VAR simulations through the antocorrelation of each asset class with its own lagged value, and more significantly, through the highly persistent autoregressive coefficients on the state variables.

Bankruptcy of insurance providers may take place both in normal times and rare disasters (rare events alone would likely understate the insolvency risk). For the former, it is assumed that an insurance provider fails with a probability of 0.15 percent per annum (uniform distribution), based on Moody's global analysis of default probability for corporate bonds rated A for 1970-2005. In disasters, the probability of insurer bankruptcy is assumed to be twice as that of government bond default. Value losses of insurance contracts in normal times and disasters are each assumed to be stochastic, in the empirical range of economic contraction in Barro (2006).

Table 2 summarizes the simulated rates, returns, and bankruptcy risks.[4] The basic statistics show that the incorporation of rare disasters significantly lowers the expected asset returns and increases their volatility. This comprehensive modeling facilitates a more realistic, perhaps even somewhat conservative, assessment of TDF risk-return tradeoffs, with due considerations of "fat tails" of possible market crashes and bankruptcies, as well as booms.

[Table 2 here]

Mutual funds charge certain fees and expenses. Wealth and income generated by mutual funds vary substantially with different levels of fees, arising from factors such as the bargaining power of the investors, market competition, product differentiation, etc. TDFs here are assumed to charge 75 basis points on account balances, regardless of asset compositions. This is the average level of expense ratio among TDFs on the market that are offered to institutional customers, as reported in Table 3. This analysis compares investment outcomes net of these expenses. The wealth delivered to investors would be significantly lower if expenses on retail terms were assumed.

[Table 3 here]

IV. Risk-Return Tradeoffs of TDFs: Simulated Results

Early-Career Workers

We initially evaluate TDFs in terms of the amount of retirement wealth accrued upon retirement and the attendant level of risk. All terminal values are adjusted into real terms by simulated inflations. Our analysis considers a hypothetical, prototypical DC plan participant who from the start of her career voluntarily selects or involuntarily defaults into one of the five life-cycle funds in Figure 1. She is assumed to earn $40,000 at age 25. Until age 55, she receives annual wage growth that is equal to 1 percent in real terms plus inflation rate (stochastically simulated through the VAR). Then the wage raise is equal to the inflation rate, thus no real growth, until retirement at age 65. The combined employer and employee contribution to her DC account is assumed to be 9 percent of pay.

Table 4 reports the probability distribution of realized inflation-adjusted retirement wealth for this long-horizon investor, out of a large number of simulations (20,000 40-year series). The 5th and 95th percentiles of terminal balance indicate "bad" and "good" outcomes, respectively. The 1st and 99th percentile simulated outcomes indicate the magnitude of extreme values.

Two initial inferences can be made. First, investment risk remains substantial regardless of which TDF is utilized. The bad investment outcomes will be deeply disappointing for investors holding higher expectations (say, around the "mean") which may have been illustrated to them. As such, while it is possible for a TDF to deliver a superb outcome, it

[4] Details of the estimation and simulations are described in a technical appendix, available from the authors upon request.

is illusory to expect a TDF to ex ante guarantee a certain balance on the target date, such as would more likely occur with, for instance, a cash balance pension plan accrued over a long career. Results in panel B, in contrast to panel A, show that the occurrences of rare economic disasters can devastate retirement wealth. The expected average wealth balance in panel B is lower because disasters skew the distribution of outcomes substantially to a lower end. The upper end of outcomes is affected to a lesser degree. Tables and discussions hereafter focus on results with incorporation of rare disasters.

Second, the differential in final balances among these five TDFs is small. After 40 years of investment, the highest average real balance is about $356,000, from TDF3E, approximately $19,000 higher than the lowest mean, from TDF2E. The worst outcomes (1^{st} percentile) differ even less among these five TDF families. This is because of the frequent switch-overs of equity exposures in the glide paths. For instance, TDF2E starts with a greater equity share than TDF5E's, crosses the path of TDF5E in the investor's mid-40s and settles with a lower equity position at retirement.

[Table 4 here]

Mid-Career Workers

We next look at the possible outcomes for a mid-career DC plan participant who invests in a TDF for ages 50-65 (Figure 2 glide paths). She is assumed to have an initial account balance of $200,000 and earn $75,000 at age 50. Other assumptions are identical to those for the early-career worker. Table 5 reports the range of simulated terminal wealth at 65.

Generally, a higher equity allocation produces greater wealth balance in expectation (median and mean outcomes). These TDFs largely maintain their relative positioning of equity exposure in the 15 years before retirement, which makes the risk-return tradeoffs clearer: for instance, TDF1M, with the highest equity allocation, has the potential of generating about $1 million ($95^{th}$ percentile outcome), a sizable difference of some $198,000 from the corresponding outcome at that percentile of TDF4M. When markets perform poorly, the downside risk is mitigated in the TDF with lower equity exposure (and lower standard deviation). At the 1^{st} percentile outcomes, TDF4M outperforms TDF1M by about $4,000 in real terms. The mitigation is thus fairly limited, which demonstrates the universal destruction of wealth in economic catastrophes.

[Table 5 here]

Workers Approaching Retirement

Last, we examine the risk-return tradeoffs for a late-career investor who starts utilizing a TDF just 5 years before retirement (glide paths in Figure 3). The worker is assumed to earn $100,000 at age 60 and have an account balance of $500,000.

As reported in Table 6, higher equity exposure again generally implies opportunities for a greater wealth balance. If the top priority for a retiring investor, however, is protection of her wealth, ahead of the pursuit of growth, then certain investment strategies may dominate. This may be because, as her career is approaching the end, the worker's aversion to risk increases as she has few working years to make up investment losses and intends to use exclusively a fixed income strategy in her retirement. Despite the general shift from equity to bonds and cash towards the target date in TDFs, poor investment performance may still substantially erode an investor's TDF balance. Specifically, the 1st and 5th percentile outcomes in Table 6 are far below the investor's initial principal plus new contributions. A TDF with lower equity exposure will mitigate this downside risk – for instance, the lower-end outcomes in TDF5R are significantly higher than those in TDF1R, approximately $147,000 compared to $113,000 at the 1st percentile outcomes. TDF5R also has a lower standard deviation.

Investors may assess the reward from equity investment by adjusting for the added risk or variability in returns. For this purpose, we calculate the Sharpe ratio, which measures the excess return (or risk premium) per unit of risk in an investment portfolio. Excess returns here are defined as the difference between TDF returns and cash returns over the whole investment horizon. The Sharpe ratio is then calculated as the mean divided by the standard deviation of the excess returns. The Sharpe ratios in the last column of Table 6 indicate that TDF4R and TDF5R provide greater risk-adjusted returns than TDFs with larger equity exposures. These results are compatible with the essence of TDFs that retiring workers are generally better off by reallocating their wealth into safer assets.

[Table 6 here]

Income Strategies for Retirees

The analysis thus far is complete for investors who are only concerned about their "terminal" balance at the point of retirement or even considering the possibility of early withdrawals, in-service or upon job exit. Others, however, who have a broader and longer-term viewpoint, may consider the ultimate goal of a retirement plan, which is to produce income once retired from work.

We consider three alternative strategies for income once TDF investors are retired: a systematic withdrawal of a fixed percentage of account balances, a systematic withdrawal of a fixed nominal amount, or a one-time complete conversion at end of age 65 to a life annuity with fixed nominal lifetime payouts. The systematic withdrawal strategies carry the risk of outliving wealth but keep the possibility of leaving a bequest and liquidity for emergencies, while a fixed payout life annuity provides nominal income stability and insurance against longevity risk. Specifically, the fixed percentage is set to 7 percent and the fixed nominal amount $55,000 (which is roughly equal to 7 percent of the median TDF balance at retirement). These income amounts are intended to be similar to the median level of nominal annuity payout that is delivered by a single premium straight immediate life annuity (see below the assumptions for annuity pricing). Assuming higher (lower) percentages or amounts would by construction generate lower (higher) fund balances, with the income outcomes being less (more) sustainable.

The underlying assets for fixed life annuities are assumed to be invested in nominal bonds. The calculation of the annuity factor uses the government bond yield, which is stochastic through time and is jointly simulated in the VAR model. Insurance companies also invest in corporate bonds, getting somewhat higher yields, but we assume that the credit spread is used to cover investment expenses and any losses from bond defaults. The annuity pricing also uses annuitant (unisex) life table to reflect adverse selection in the voluntary immediate annuity market, and there is a load of 10 percent to cover administration, marketing and other costs. Also note that the annuity payouts reported below reflect possible bankruptcies of annuity providers, which reduce payouts by the randomly realized magnitudes, permanently for the annuitant's remaining life. Taken together, these are conservative assumptions for life annuities.

The survival of retirees from age 66 onward is simulated based on a general population unisex life table. Observations of account balance and income are ignored in the years following the simulated death of an investor. The probability distributions of retirement income are reported in Tables 7 through 9 and Figures 4 through 6, for the three income strategies, respectively. For clarity, these income results are generated by making systematic withdrawals from fund balances over ages 65 through 100 or by converting age-65 balances entirely into life annuities. The range of age-65 balances was reported in Table 6.

For the fixed percentage systematic withdrawal, TDF1R and TDF2R exhibit the best overall outcomes, even though they have the highest equity exposure. Through this withdrawal mechanism, these two funds deliver more volatile incomes (larger standard deviations), but the probabilities of income falling below $25,000 over the retirement life are lower than for other TDFs (last column of Table 7). They do imply slightly higher shortfall risks in the early years of retirement, as shown in Figure 4. In contrast, TDF3R, TDF4R and TDF5R, though with lower standard deviations, limit the rate of wealth growth and thus distribute lower income for consumption at advanced ages, although in economic disasters they perform slightly better. TDF3R, in this respect, may represent a reasonable compromise, especially for quite risk-averse investors.

[Table 7 here]
[Figure 4 here]

For the fixed amount withdrawal, the relative positioning of the TDFs remains the same as in the fixed percentage case, but the differential of risks and returns among TDFs is narrower (Table 8). Several reasons account for this result: First, the fixed nominal amount withdrawal plus the same stochastic inflations yields identical probability distribution of real incomes across TDFs, if full amount withdrawals *were* always available (i.e., no depletion of wealth). Second, the fixed amount withdrawal is less likely to preserve resources for later life but the depletion generally happens only at advanced ages. The income flow associated with one TDF may last a few more years than with another, for instance, until age 85 versus age 90. The real value of the nominal withdrawals at these advanced ages, however, may have fallen substantially, owing to 20+ years of inflation. High mortality rates have also eliminated many observations of high values. Thus, the risk profiles of income falling below $25,000 become compact (plotting not shown). Third, when investment returns are high, across all the TDFs, a fixed nominal dollar withdrawal will leave assets for a bequest (not shown here), not boosting income. We see that the risk of wealth being entirely depleted and thus income being zero is lowest for TDF2R and TDF3R, and highest for TDF4R, the fund with the highest allocation to cash.

[Table 8 here]

If investors plan to annuitize their wealth upon retirement and want to integrate this income strategy with their choice of TDF investment in working years, the results in Table 9 offer a useful reference and give a different indication of investment strategy than if systematic withdrawals are being made. TDF4R and TDF5R here give more security in terms of lower volatility (standard deviation) of income and better performance in down markets, owing to their lower equity exposure, at some cost of forgoing upside potential. Note that TDF5R is somewhat more secure than TDF4R, albeit with a higher equity exposure at retirement, likely because TDF5R has a larger bond position at retirement, which serves as a better hedge to the annuity purchase.[5] And note that the annuity strategy generally produces higher income flows, across probability percentiles and TDFs, compared to the systematic withdrawal strategies, owing to its mortality pooling properties, although at the cost of a loss in bequest potential and liquidity.

[Table 9 here]

V. Conclusions

Through stochastic simulations, we compare risk-return tradeoffs for target-date funds that have different initial asset allocations and subsequent glide patterns. Target-date funds are an improvement over the status quo given that most DC plan participants seem to hold non-optimal portfolios. Target-date funds are nonetheless risky and the pursuit of wealth growth through equity investment is accompanied with shortfall risks because the expected returns through the better diversified, age-specific, and dynamically reallocated funds are no guarantee.

The obvious way to reduce "terminal" balance risk is to reduce equity exposure toward the end of a career and increase cash. This, however, is not always compatible with income strategies over many years in retirement. If a life annuity is the desired income strategy, the lower risk strategy is a larger allocation to bonds, rather than to cash. Basic living needs continue regularly throughout an individual's life and are therefore subject to longevity risk which may best be handled with a life annuity. If a fixed systematic withdrawal is the desired income strategy, a larger allocation to equities generally has a better prospect of delivering income for advanced ages. A systematic withdrawal strategy,

[5] Warshawsky (2007) discusses the trend and volatility of annuity prices and the sensitivity of annuity payout levels to interest rate changes at the time of purchase. Smith and Judd (2009) discusses the switch from growth to protection assets around retirement for DC plan participants and particularly the selection of cash-bond mixes to meet the priorities of lump-sum withdrawal versus annuity price hedging.

however, presumes that the participants are able to weather storms and will not panic at the first sight of trouble in investment. A more aggressive TDF portfolio generally decreases the chance of running out of funds in retirement but it also increases the shortfall amount in the "fat tail" events. If participants are prone to panic or are living on the edge (shortfall is very painful), a more conservative strategy is appropriate. Indeed, the "middle" equity allocations seem to have good risk-return properties across the distribution of outcomes for both types of systematic withdrawal approaches.

The optimal asset allocation depends on a number of specifics for individuals, including personal characteristics and other benefits offered. For instance, if a company offers a defined benefit pension plan in parallel, the safe pension benefit establishes an income floor and thus accommodates a more aggressive TDF portfolio. Similarly lower income individuals get a significant portion of their retirement benefits from Social Security, which would allow for a larger portion of their individual account balance in equity. As a result of the complexity and variety of situations, it is challenging for regulations or legislation to set asset allocation constraints that foster "mass suitability" for a majority of TDF investors. Rather, simple, understandable and realistic disclosure plus enhanced sponsor and participant understanding and evaluation is essential, so that the appropriate TDF options can be selected.

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Table 1. Equity allocations in retirement accounts by age of workers

Age	0%	1-24%	25-49%	50-74%	75-99%	100%	All	% of sample
	Percentage of assets allocated to equity							
25-34	19.6	9.0	17.5	17.8	15.3	20.9	100.0	16.7
35-44	15.7	9.3	16.2	23.1	13.4	22.3	100.0	25.5
45-54	13.5	10.3	20.2	25.4	13.0	17.7	100.0	31.6
55-64	17.2	8.5	16.5	23.0	13.4	21.5	100.0	26.3
Total	16.0	9.4	17.8	22.9	13.6	20.4	100.0	100.0

Notes:

1. Retirement accounts include DC plans for current and prior jobs and all IRAs.
2. The sample includes heads and spouses if they have a positive account balance and at least one household member is working.

Source: Authors' calculations based on Survey of Consumer Finances 2007.

Table 2. Statistics of simulated rates, returns and bankruptcies

A. Simulated annual probabilities of disaster, default and bankruptcy (%)

	Rare disaster large equity contraction	Government bond default	Insurer bankruptcy
Mean	1.70	0.67	1.36
Std. Dev.	0.09	0.06	0.09

B. Simulated rates and returns (%)

		Real			Nominal			
Without disasters	Inflation	T-bill	Stock	Bond	T-bill	Stock	Bond	Bond yield
Mean	4.0	1.1	4.7	2.4	5.1	8.8	6.4	6.2
Std. dev.	2.8	2.1	17.6	7.4	2.6	17.2	6.7	2.5
With disasters								
Mean	4.8	0.7	3.6	1.7	5.5	8.4	6.5	6.5
Std. dev.	6.5	6.2	24.2	11.9	2.8	20.8	7.9	2.7

C. Simulated loss of insurance contract value (%) conditional on bankruptcy

Min	Median	Max	Mean	Std. Dev.
19.1	28.5	87.3	33.1	12.9

Source: Authors' simulations.

Table 3. Expense ratios for target-date funds (%)

	Min	Mean	Max	No. of Obs.
Institutional pricing only	0.18	0.75	1.10	118
Retail & institutional pricing	0.18	1.24	2.45	644

Source: Authors' data collection.

Table 4. Simulated Terminal Wealth at age 65 ($000, real) for an Early-Career Investor

A. Without consideration of economic disasters

	Percentiles of outcomes								Std.
	1st	5th	25th	50th	75th	95th	99th	Mean	Dev.
TDF1E	176.8	220.1	298.3	369.1	455.9	626.7	779.9	388.9	126.8
TDF2E	183.7	222.9	292.8	352.0	426.2	564.2	679.3	367.6	106.2
TDF3E	181.1	223.6	301.1	371.2	457.1	625.1	774.1	390.7	125.5
TDF4E	185.0	224.6	296.6	358.3	435.3	581.5	703.7	374.7	110.6
TDF5E	182.7	223.7	298.3	363.1	444.7	599.6	734.2	381.4	117.1

B. With consideration of economic disasters

	Percentiles of outcomes								Std.
	1st	5th	25th	50th	75th	95th	99th	Mean	Dev.
TDF1E	33.9	91.1	238.6	342.1	451.8	654.4	839.0	353.9	171.5
TDF2E	34.0	88.8	237.4	332.3	427.3	595.1	748.7	336.5	153.0
TDF3E	33.1	89.6	241.1	345.3	454.3	655.2	836.8	355.8	171.8
TDF4E	33.5	87.8	239.5	337.5	436.4	612.2	773.8	342.9	158.9
TDF5E	32.9	88.4	240.3	340.6	443.6	629.6	799.2	348.1	163.6

Source: Authors' simulations.

Table 5. Simulated Terminal Wealth at age 65 ($000, real) for a Mid-Career Investor

	Percentiles of outcomes								Std.
	1st	5th	25th	50th	75th	95th	99th	Mean	Dev.
TDF1M	47.8	129.3	315.4	446.2	617.2	1020.6	1540.3	502.1	331.7
TDF2M	50.3	130.8	321.2	438.5	587.5	916.0	1335.3	478.6	270.9
TDF3M	52.6	134.7	319.5	434.2	579.7	900.0	1296.3	473.0	263.2
TDF4M	52.0	131.5	320.5	424.3	551.0	822.8	1161.1	451.7	228.3
TDF5M	53.5	135.1	321.3	428.2	562.1	849.4	1207.0	459.9	238.3

Source: Authors' simulations.

Table 6. Simulated Terminal Wealth at age 65 ($000, real) for a Retiring Investor

	Percentiles of outcomes								Std.	Sharpe
	1st	5th	25th	50th	75th	95th	99th	Mean	Dev.	Ratio
TDF1R	112.9	358.8	525.8	651.2	801.4	1087.2	1364.6	676.6	237.7	0.58
TDF2R	119.7	372.7	532.0	647.3	785.5	1041.1	1284.2	667.8	217.6	0.60
TDF3R	127.6	378.6	532.7	643.2	774.5	1018.9	1246.8	662.0	208.2	0.60
TDF4R	138.6	399.5	538.1	635.4	748.7	950.2	1137.9	647.8	181.7	0.63
TDF5R	146.5	417.5	541.3	625.8	720.7	887.0	1030.4	631.7	156.6	0.65

Source: Authors' simulations.

Table 7. Probability distribution of simulated income outcomes ($000, real) over all years in retirement, conditional on survival - systematic withdrawal of fixed 7% of balance

	Percentiles of outcomes								Std.	Prob.
	1st	5th	25th	50th	75th	95th	99th	Mean	Dev.	<$25k
TDF1R	2.3	6.7	18.8	29.7	42.4	67.0	95.1	32.6	20.6	39.0
TDF2R	2.4	6.7	18.6	28.9	40.7	62.3	85.1	31.2	18.3	40.3
TDF3R	2.6	6.8	17.9	27.7	38.9	58.4	77.9	29.6	16.6	43.0
TDF4R	2.7	6.6	16.2	25.4	35.7	52.0	66.1	26.9	14.3	48.9
TDF5R	2.5	6.6	17.4	26.9	36.9	52.1	65.7	27.9	14.2	44.9

Source: Authors' simulations.

Table 8. Probability distribution of simulated income outcomes ($000, real) over all years in retirement, conditional on survival - systematic withdrawal of fixed nominal $55,000

	Percentiles of outcomes								Std.	Prob.	Prob.
	5th	10th	25th	50th	75th	95th	99th	Mean	Dev.	<$25k	= $0
TDF1R	0.0	3.0	18.4	28.8	37.5	46.8	52.8	27.1	13.8	39.9	9.4
TDF2R	0.0	3.8	18.4	28.8	37.5	46.8	52.8	27.1	13.8	39.9	9.2
TDF3R	0.0	3.6	18.3	28.8	37.5	46.8	52.8	27.0	13.8	40.0	9.2
TDF4R	0.0	1.3	17.9	28.7	37.4	46.8	52.8	26.8	14.0	40.5	9.8
TDF5R	0.0	3.4	18.2	28.7	37.5	46.8	52.8	27.0	13.9	40.1	9.2

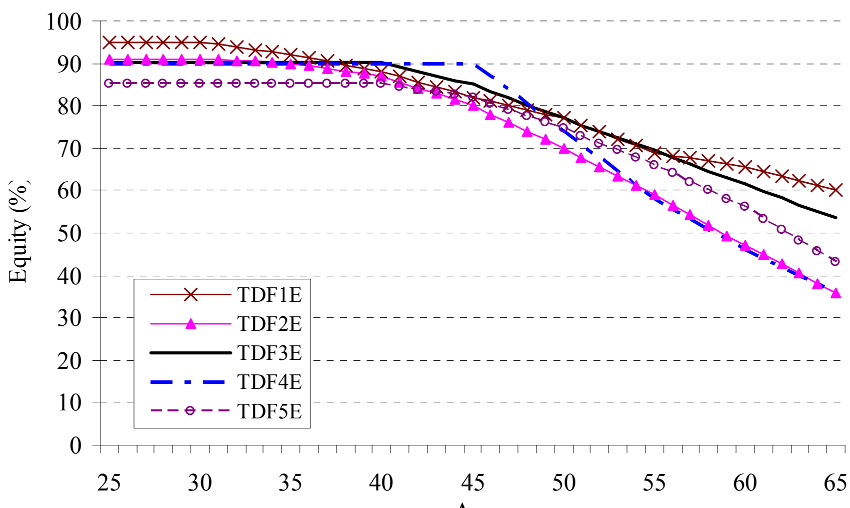
Source: Authors' simulations.

Table 9. Probability distribution of simulated payouts ($000, real) over all years in retirement, conditional on survival - single premium fixed nominal payout life annuity

	Percentiles of outcomes								Std.	Prob.
	1st	5th	25th	50th	75th	95th	99th	Mean	Dev.	<$25k
TDF1R	3.0	9.3	23.9	36.2	51.0	79.3	109.9	39.4	22.7	27.1
TDF2R	3.1	9.5	24.1	36.1	50.2	76.5	103.9	38.9	21.5	26.8
TDF3R	3.2	9.6	24.1	35.9	49.8	75.2	101.7	38.5	21.0	26.9
TDF4R	3.4	9.9	24.1	35.6	48.6	71.5	94.2	37.6	19.4	26.7
TDF5R	3.5	10.0	24.1	35.2	47.2	67.5	86.4	36.6	17.9	26.8

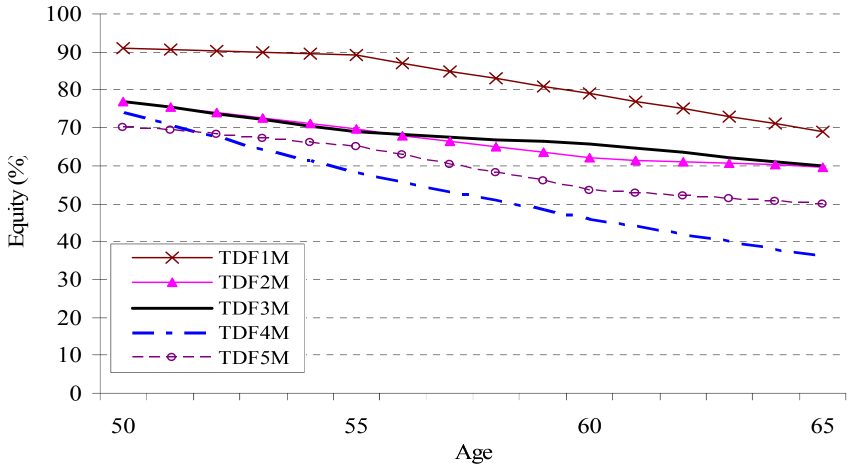
Source: Authors' simulations.

Figure 1. TDF Asset Allocations for Early-Career Workers



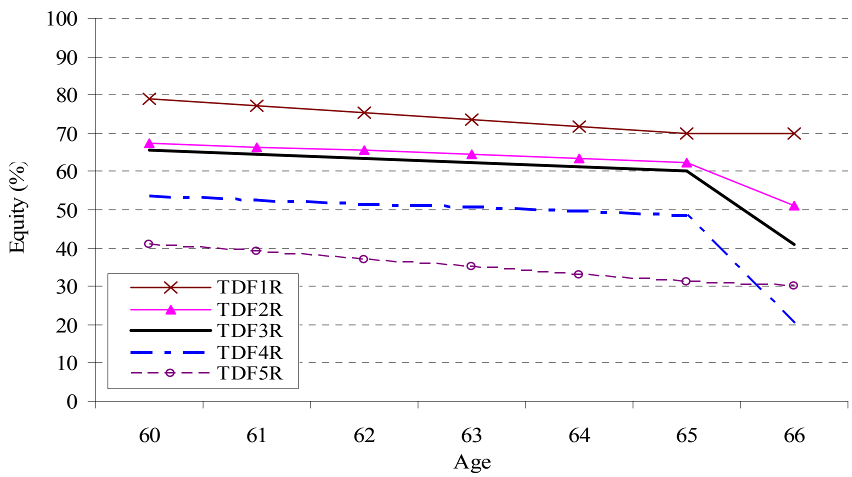
Notes: The percentiles of TDFs are identified by equity allocations in 2050 TDFs, with bond and cash allocations collected correspondingly. The glide paths are constructed by connecting all TDFs for each fund family. Allocations for ages between target dates are linearly interpolated.
Source: Authors' data collection from Morningstar and TDF providers' websites as of May 31, 2009.

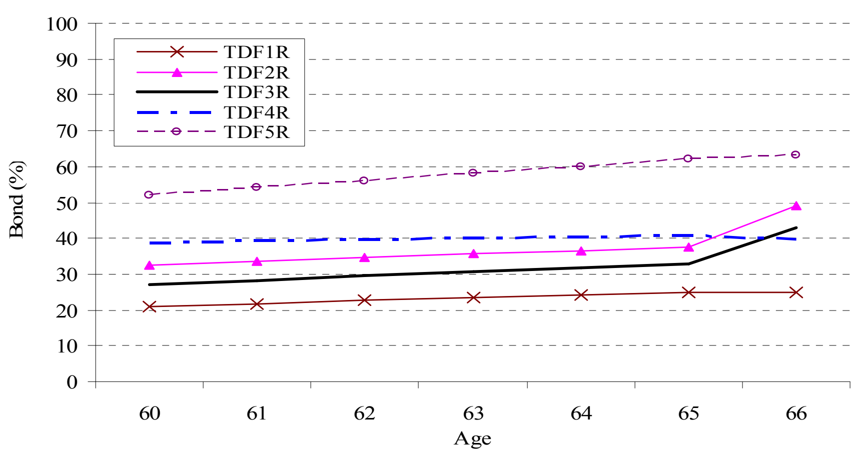
Figure 2. TDF Asset Allocations for Mid-Career Workers

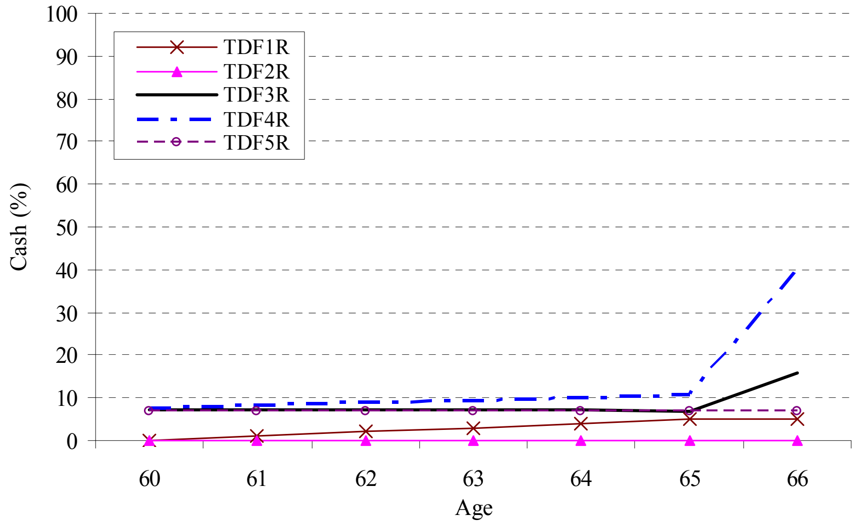


Notes: The percentiles of TDFs are identified by equity allocations in 2025 TDFs, with bond and cash allocations collected correspondingly. The glide paths are constructed by connecting all TDFs for each fund family. Allocations for ages between target dates are linearly interpolated.
Source: Authors' data collection from Morningstar and TDF providers' websites as of May 31, 2009.

Figure 3. TDF Asset Allocations for Retiring Workers

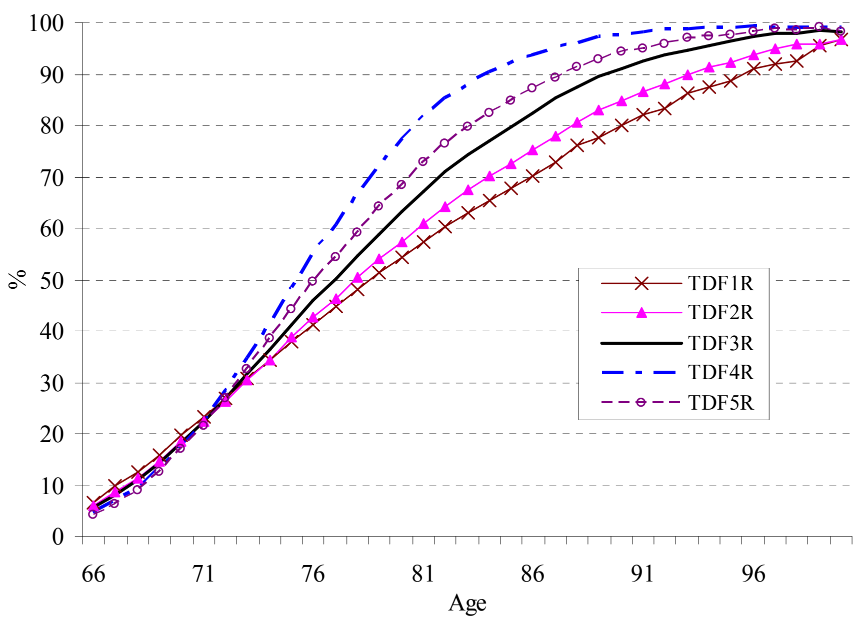






Notes: The percentiles of TDFs are identified by equity allocations in 2015 TDFs, with bond and cash allocations collected correspondingly. The glide paths are constructed by connecting all TDFs for each fund family. Allocations for ages between target dates are linearly interpolated.
Source: Authors' data collection from Morningstar and TDF providers' websites as of May 31, 2009.

Figure 4. Probability of real income falling below $25,000 – fixed percentage withdrawal



Source: Authors' simulations.