NBER WORKING PAPER SERIES

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Working Paper 26684
http://www.nber.org/papers/w26684

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
January 2020

This research is part of the NBER programs on Aging and Labor Studies and the Household Finance Working Group, and it was undertaken pursuant to a grant from the US Social Security Administration (SSA) to the Michigan Retirement Research Center (MRRC). This research support is gratefully acknowledged along with that of the Pension Research Council and Boettner Center at The Wharton School of the University of Pennsylvania, and Vanguard. The authors would like to thank Gary Koenig, Alberto Rossi and Jean Young for helpful comments, and Yong Yu for exceptional research assistance. They acknowledge Vanguard's efforts in the provision of anonymized recordkeeping data under restricted access conditions. All findings, interpretations, and conclusions represent the views of the authors and not those of the Wharton School or the Pension Research Council, the SSA, any agency of the Federal Government, Vanguard, the MRRC, or any other institution with which the authors are affiliated.

At least one co-author has disclosed a financial relationship of potential relevance for this research. Further information is available online at http://www.nber.org/papers/w26684.ack

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JEL No. D12,D14,D91,G5,G51,J32

ABSTRACT

Target date funds in corporate retirement plans grew from $5B in 2000 to $734B in 2018, partly because federal regulation sanctioned these as default investments in automatic enrollment plans. We show that adopters delegated pension investment decisions to fund managers selected by plan sponsors. Including these funds in retirement saving menus raised equity shares, boosted bond exposures, curtailed cash/company stock holdings, and reduced idiosyncratic risk. The adoption of low-cost target date funds may enhance retirement wealth by as much as 50 percent over a 30-year horizon.

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Target Date Funds and Portfolio Choice in 401(k) Plans

Although U.S. employers are legally responsible for selecting and overseeing investment options in the 401(k) plans offered to their workers, employees have traditionally been responsible for selecting their own portfolios given the fund menus offered.[1] A concern with this approach is that many participants appear to be ill-equipped to make these portfolio decisions, potentially undermining old-age retirement security, due to financial illiteracy or behavioral biases.[2]

This paper shows how the introduction of target date funds (TDFs) into 401(k) plans has fundamentally altered the decision-making dynamic in U.S. defined contribution retirement saving plans. A target date fund menu consists of a series of fund offerings with portfolio allocations described in terms of an expected year of retirement; usually offered in five-year increments (e.g., a 2015, 2020, etc., fund), a target date fund series may include up to a dozen funds. Participants in voluntary choice plans must actively select among target date and other fund offerings; by contrast, a participant in an automatic enrollment plan is initially defaulted into a single target date fund based on the employee's current age and assumed retirement date (usually age 65), with the option to move to other investments subsequently.

Target date fund assets in 401(k) plans have grown phenomenally over time, from $5B in 2000 to $734B in 2018 (ICI, 2019). In part, this growth was spurred by a Department of Labor regulation issued under the 2006 Pension Protection Act designating target date funds as an eligible default investment option for automatic enrollment plans.[3] By 2018, 80 percent of 401(k) plans offered these funds (ICI, 2019), and

[1] Here we use the term 401(k) plans to refer broadly to private-sector defined contribution plans which can include profit-sharing, money purchase, and 403(b) plans along with 401(k) plans.

[2] Research on the role of financial illiteracy and behavioral biases in investing and savings decisions includes Bekaert, Hoyem, Hu, and Ravina (2017), Benartzi and Thaler (2001. 2002), Beshears, Choi, Laibson and Madrian (2018), Goda, Levy, Manchester, Sojourner and Tasoff (2019), Lusardi and Mitchell (2007, 2011, 2104), Mitchell and Lusardi (2011), Mottola and Utkus (2008), Dimmock, Kouwenberg, Mitchell, and Peijnenberg (2016), and van Rooij, Lusardi, and Alessie (2011).

[3] The Department of Labor regulations were effective December 24, 2007. 72 Fed. Reg. 60451. Eligible "qualified default investment alternatives" (QDIAs) include target date funds, traditional balanced funds, and managed account advice services. QDIA regulations provide sponsors so-called 404(c) protection for participant portfolio choices, meaning there is a presumption that employers are not liable for participant portfolio decisions when participants hold QDIAs. The sponsor retains liability for selecting and monitoring the QDIA itself.

two-thirds of new 401(k) plan entrants were automatically enrolled, with target funds the dominant choice for default investments (Vanguard, 2019). This rising reliance on automatic enrollment and default portfolio choice in the U.S. conforms to a global move toward default portfolio choice in defined contribution systems (OECD, 2015).

Compared to other multi-asset class portfolios such as traditional balanced and risk-based lifecycle funds, a target date family offers retirement savers two unique advice-related features. First, each fund is identified with an anticipated retirement year which serves as an implicit recommendation regarding which types of investors should hold each fund. If investors must make their own portfolio choices, the date labeling transforms a potentially complex decision about how to assemble a portfolio with the available funds on the menu into a simpler decision heuristic, namely to simply select the fund associated with the employee's anticipated retirement date. [4] Second, target date risk levels are automatically rebalanced over time by fund managers who follow an "equity glide path," reducing risk as participants near their target dates. [5]

In what follows, we evaluate how the introduction of target date funds into 401(k) investment menus has reshaped participants' portfolio choice decisions, drawing on an anonymized, restricted-access longitudinal dataset from Vanguard, a major 401(k) plan administrator and investment manager. The target date funds we study are almost exclusively indexed portfolios, diversified across global equity and fixed asset classes, with management fees under 20 basis points. As a result, our dataset represents a real-world benchmark for the provision of low-cost, highly diversified professional portfolio advice to an important group of nonprofessional investors.

To assess the impact of target date fund introduction, we examine participant adoption and portfolio exposures one year after the first appearance of the funds in the 401(k) investment menus. We show that

[4] Prior to the advent of target date funds, no investment funds provided age-related rebalancing in 401(k) plans.

[5] Here we take no stance on the desirability of a declining equity share with age. Some analysts favor it based on labor income profiles with age (e,g., Campbell and Viceira, 2002; Cocco, Gomes and Maenhout, 2005), while others do not (e.g., Basu, Byrne and Drew, 2011).

28.4 percent of new entrants into voluntary enrollment plans adopted target date funds in their retirement saving accounts, whereas only 10.2 percent of existing employees (workers in the plan prior to the funds' appearance) switched out of existing investments into these funds. This difference we describe as an *active choice effect*, reflecting the fact that new entrants in voluntary enrollment plans had to make an active choice to join the 401(k) plan, whereas existing employees faced a discretionary choice of whether to switch to new options. By contrast, in plans with new-hire automatic enrollment, 78.7 percent of new entrants adopted target date funds, representing a substantial *default effect*. In addition, 21.7 percent of existing employees in these plans invested in the funds, double the rate of existing employees in voluntary choice plans. We take this latter result as a *default-related endorsement effect*: the employer's selection of target date funds as a default investment for new hires influenced existing employees' willingness to switch to the funds. Similar effects are observed for other measures, such as the propensity to be a *pure target date investor* (investing all of one's savings in a single target date fund) or a *mixed target date investor* (combining a target date fund with other options).

In terms of portfolio effects, adoption of target date funds had sizeable effects on equity share and risk factor exposures: relative to non-target date investors, participants' equity share rose an average of 24 percentage points for pure investors, and by 13 percentage points for mixed investors. Pure and mixed target date investors' equity share also declined with age, whereas non-target date investors had a hump-shaped equity share by age. As a result of increased equity and bond market exposures, expected factor returns for pure investors rose by 2.3 percent per year and for mixed investors by 1.7 percent per year, relative to non-target date investors. Holdings in cash and company stock fell, as did uncompensated idiosyncratic risk, in our sample of indexed target date funds.

Accordingly, the introduction of target date funds produced an important shift away from participants' 401(k) plan portfolio selections and toward the target date managers selected by employers. This change will have sizeable benefits: for instance, we estimate that improved returns could raise expected retirement wealth by as much as 50 percent over a 30-year savings horizon, for a pure investor in a low-cost target date series. Inasmuch as employers may have introduced the funds responding to concerns over

participants' poor portfolio construction patterns, we cannot assert that the results are completely attributable to the 'treatment effect' of target date fund introduction. Nevertheless, employees who moved into the target date funds could have previously made the portfolio changes on their own and realize the potential benefits, yet they did not.

Our paper is informed by an extensive literature examining how default arrangements shape employee savings and investment decisions, though no prior study has explored the varieties of 'choice architecture' studied here.[6] There is also research asking whether peoples' portfolio choice is influenced by investment illiteracy or behavioral biases,[7] suggesting that retirement investment menus can shape, or "frame," portfolio allocation patterns due to inertia or naïveté,[8] or in reaction to excessive complexity (also known as "choice overload").[9] Our contribution is to show how introducing target date funds into the 401(k) investment menu substantially altered portfolio outcomes across a diverse set of firms in voluntary choice and automatic enrollment as well as non-autoenrollment settings.

In what follows, we describe key elements of the plan choice architecture relevant to the target date setting. We then turn to an empirical analysis of adoption behavior and changes in portfolio composition, before versus after the introduction of the new fund family. We conclude with a discussion of implications of our findings for household finance and for the potential benefits that scalable, low-cost investment advice can provide.

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[6] On the savings side, see Carroll, Choi, Laibson, Madrian, and Metrick (2009); Choi, Laibson, and Madrian (2004); Choi, Laibson, Madrian, and Metrick (2003, 2004, 2006); Clark and Young (2018); and Madrian and Shea (2001). On portfolio allocation, see Agnew, Balduzzi and Sunden (2003); Ameriks and Zeldes (2004); Benartzi (2001); Benartzi and Thaler (2001, 2002); Benartzi, Peleg and Thaler (2007); Calvet, Campbell, and Sodini (2009); Mitchell, Mottola, Utkus and Yamaguchi (2006a, 2006b); and O'Donoghue and Rabin (1999; 2001).

[7] See Barber and Odean (2001); Bekaert, Hoyem, Hu, and Ravina (2017); Benartzi and Thaler (2001, 2002); Beshears, Choi, Laibson and Madrian (2018); Goda, Levy, Manchester, Sojourner and Tasoff (2019); Lusardi and Mitchell (2007, 2011, 2014); Mottola and Utkus (2008); and Mitchell and Lusardi (2011); and van Rooij, Lusardi, and Alessie (2011).

[8] Examples include Agnew and Szykman (2005); Elton, Gruber and Blake (2007); Huberman and Jiang (2006); Brown, Liang and Weisbenner (2007); McDonald, Richardson, and Rietz (2019); Thaler and Sunstein (2008); Tang, Mitchell, Mottola, and Utkus (2010); and Pool, Sialm, and Stefanescu (2016).

[9] See for example Iyengar, Huberman, and Jiang (2004); and Iyengar and Kamenica (2010).

401(k) Choice Architecture and Participant Portfolio Choice

Our analysis draws on administrative records for 880 defined contribution plans that introduced target date funds between January 2003 and June 2015 (a period of 12.5 years or 150 months). These data were provided by Vanguard, a leading US 401(k) recordkeeper, on an anonymous, restricted-access basis.[10] Table 1 illustrates how the target date funds related to their target maturity dates, and it also indicates how each fund utilized a different mix of passively-managed U.S. equity (including large-, mid- and small-capitalization stocks), international equity (both developed and emerging markets), and high-quality domestic bonds.[11] For instance, total equity exposure in the funds for young participants (column 7) averaged 90 percent (in the 2040 through 2055 Funds), versus 30 percent for participants in the Income Fund (intended for retirees).[12]

Table 1 here

To analyze target date fund portfolio choice, we selected a research sample of over 1.2 million active participants from the 880 plans that introduced target date funds January 2003-June 2015.[13] Both adoption and portfolio composition statistics were gathered for each plan 12 months following the first appearance of target date funds in the investment menu. Plan participants in the firm prior to the adoption of target date funds and still in the plan one year later were classified as *existing participants*; those entering the plan after the target date fund introduction date and still in the plan at the 12-month window were classified as *new entrants*.

[10] All target date funds offered were Vanguard-managed.

[11] In February 2013 the funds added an allocation of international bonds. We illustrate the allocations at the end of 2010 because they were typical of the period we study.

[12] The Vanguard funds were all indexed except for holdings of inflation-indexed bonds available to only a small fraction of retired participant portfolios; accordingly, we refer to the funds as indexed. Fund fees were below 0.20% during the 2003-15 period (at the end of our analysis period, even lower-cost versions of the target date funds were introduced in a few large plans). During 2010, a small number of target date funds offered by other investment managers were introduced but these accounted for below 1% of participants studied.

[13] Active 401(k) participants were those who are currently contributing to their employer's retirement plan. We only include plans for which we observe plan and participant records both prior to and subsequent to the introduction of the target date funds. Plans transferring to the Vanguard recordkeeping service for the first time during our sample period and adopting target date funds at that point are excluded from our sample because we cannot observe plan holdings prior to the funds' introduction.

This distinction is important for understanding portfolio choice decisions. When target date funds first arrive in the 401(k) menu, *existing participants* must decide whether they will switch their portfolios to the new funds, away from funds previously selected. Factors influencing this decision could include the appeal of the key features of target date funds, namely their labeling as a form of investment advice and their automatic age-based rebalancing feature. Factors hindering adoption could include behavioral factors such as inertia and procrastination, as well as an endowment effect (whereby funds already owned may appear to be more valuable than those not yet owned). By contrast, *new entrants* would likely be more strongly influenced by a plan's choice architecture. In *voluntary choice* plans, new entrants making investment decisions would need a degree of financial literacy to navigate through the entire plan investment menu, compare target date funds relative to other options, and construct their portfolios on their own. *Auto-enrolled new entrants*, by contrast, would be directly invested into a single target date fund. These latter individuals could either take no action and remain in the single target date fund assigned to them, or make a switch to some other portfolio with different features.

Table 2 arrays our data by plan and individual characteristics, using period average statistics.[14] Two key outcome variables indicate the plan choice architecture shaping participants' choices: *TDFDefault,* indicating whether the target date series was designated as the plan's default option; and *New-hire auto enrollment*, indicating whether the plan automatically enrolled new hires, regardless of the type of default fund used by the plan.[15] The first column in Panel A reveals that 52 percent of participants were in plans where target date funds became the plan default.[16] One-third (32.9 percent) of participants were in plans where new hires were automatically enrolled in the firm's plan, regardless of the type of default fund used.

[14] The average statistics pertain to plan-specific 12-month windows, rather than end-of-period characteristics. Appendix Table 1 provides more detail on target date fund patterns by year.

[15] Under new-hire automatic enrollment, newly eligible participants have contributions deducted automatically from their first eligible pay (with the right to opt out); their contributions are invested in the plan's designated default fund. Our automatic enrollment indicator is for new hires only. Some employers have "swept" (i.e., automatically enrolled) existing eligible non-participants, because our dataset does not include an indicator for such "sweeps." Accordingly our estimates should be viewed as lower bounds.

[16] A plan may designate a fund as a default for several purposes, including automatic enrollment or as a fund for depositing administrative corrections.

Panel A also indicates that 24.7 percent of participants became target date investors with the advent of the new funds on the menu.[17] Two-thirds of these (15.7 percent) were pure target date investors contributing only a single target date fund, while the remaining one-third (9 percent) were mixed investors, holding a target date fund plus some other funds. The right side of Table 2 reports the percentage of pure, mixed, and non-target date investors having the plan features indicated. For instance, 72.1 percent of pure investors were in plans where the target date funds were the default, and 49.5 percent of pure investors were in plans where new hires were auto-enrolled. By contrast, fewer participants holding mixed portfolios (64.9 percent) and only 46.3 percent of non-target date fund investors were in plans where target date funds were the default. As also noted, plan menus averaged 25.6 funds in size, 48.4 percent of participants were offered employer stock as an investment option, and most employees (88.4 percent) had access to plan loans.

Table 2 here

Turning to Panel B of Table 2, we see that 19.7 percent of older participants were new entrants who joined their plans after target date fund introduction, within the 12-month observation period.[18] Other participant information included 401(k) account balances and contribution patterns, plan investments, and participant characteristics such as age, sex, household income, job tenure, and non-retirement financial wealth.[19] In terms of investor patterns, we see that pure target date investors were younger and more likely to be female, had low/moderate incomes, and held smaller account balances (Column 2, Table 2). Mixed target date fund investors had the opposite characteristics and above-average balances (Column 3). Because the panel spanned by our data included the 2008-9 financial crisis period, we also include an indicator for whether the 12-month plan window occurred during that period.

Adoption of Target Date Funds

[17] Consistent with prior studies of participant investment behavior, we measure portfolio allocations using contribution designations rather than existing portfolio holdings, as the former better reflect forward-looking intentions.

[18] Not all new entrants are new hires: while most plans do allow new hires to become immediately eligible to contribute, a few impose a 6- or 12-month waiting period.

[19] Household income and non-retirement wealth were provided to Vanguard by Acxiom; amounts are imputed using zip code (zip+4) averages.

To assess the distinct impacts of default versus active choice on participants' portfolio selection, we estimate three multivariate models of target date fund adoption. Each model relates a distinct measure of target date adoption to default, participant, plan, and other factors, as in equation (1):

$$TDFAdoption_{i,j,t} = \alpha DEFAULT + \beta PLAN + \gamma PARTICIPANT + v_i + \tau_t + w_j + \varepsilon_{i,j,t} \quad (1)$$

Here $TDFAdoption_{i,j,t}$ indicates whether employee *i* adopted a target date fund in plan *j* in month *t*, measured using total contributions to the target date fund (from both the employee and employer). Model A examines the extensive margin of target date adoption by estimating a Probit specification. Here the dependent variable takes a value of 1 if the participant had contributed to a target date fund a year after the target date funds' introduction to the menu (0 otherwise). The mean value of this time-weighted adoption rate was 24.7 percent over the 2003-15 period. Model B measures the intensive margin of adoption, where the dependent variable in the OLS equation is the share of employees' contributions directed to target date funds; the mean time-weighted value for our sample was 18.9 percent (which includes non-target date investors).[20] Model C uses a multinomial Logit framework where the dependent variable is zero if the participant was a non-target date investor (the reference category); 1 if the participant was a "mixed" target date fund investor (directing 1-99 percent of contributions to one or more target date funds); or 2 if the participant was a "pure" target date fund investor (directing all contributions to a single target date fund). In Model C, the mean time-weighted proportion of pure investors was 15.7 percent, and of mixed investors, 9.0 percent.

All three models use the dataset described in Table 2, which included all active participants in our he 401(k) sample: a single observation is available for each participant 12 months following the first appearance of target date fund in his plan menu. Explanatory variables in equation (1) include attributes of the plan default architecture, *DEFAULT,* discussed above; plus a *PLAN* vector of other characteristics such as the size of the plan menu, the availability of plan loans; and a comprehensive set of participant

[20] This figure includes both those holding target date funds and those with zero holdings.

characteristics, *PARTICIPANT*, including age, sex, income, 401(k) account wealth, and a measure of non-retirement-account financial wealth. [21]

Rather than elaborate on each estimated coefficient separately (all are reported in Appendix Table 2), Table 3 uses these estimates to derive predicted effects for existing employees and new entrants under both voluntary choice and automatic enrollment architectures. The overall probability of an employee adopting target date funds one year after they were introduced averaged 24.7 percent. In voluntary enrollment plans, 10.2 percent of existing employees adopted these funds, versus the new entrant adoption rate almost three times as large (28.4 percent). This sizeable difference we attribute to an *active choice effect* among new plan entrants: they had to actively select investments to enroll in the plan, versus existing employees who had already enrolled and only had to make the switch to the new funds. In automatic enrollment plans, 21.7 percent of existing employees adopted the funds, and 78.7 percent of auto-enrolled new entrants. The former result we interpret as due to the *endorsement effect*, whereby the employer's decision to choose the target date fund as a default investment for new entrants influenced the willingness of existing employees to switch. It is more than twice as large as the adoption rate by existing employees in voluntary enrollment plans. The latter effect is a very strong *default effect*. Panel 3 of Table 3 summarizes the relative sizes of these outcomes.

Table 3 here

The second column of Table 3 addresses the fraction of contributions that employees directed to target date funds. These effects are similar in direction and magnitude to column the first column. Column 3 shows that automatic enrollment was especially powerful in influencing participants to become *pure* target date investors, another measure of the intensive adoption margin. Again, the same three effects are at work. In terms of the active choice effect, 3.9 percent of existing employees in voluntary choice plans switched all of their contributions to a single target date fund when the funds were first introduced, while

[21] The models also control for plan-level heteroskedasticity (ν_i), time fixed effects (τ_t), and industry fixed effects, along with missing data dummies. All models also include a financial crisis control, defined here as the period September 2008-June 2009.

the figure rose to 14.5 percent for new enrollees. In terms of the default effect, 74.9 percent of automatically enrolled new entrants were pure target investors, more than five times the voluntary enrollment new entrant rate. And finally, in terms of the endorsement effect, only 3.9 percent of existing employees in voluntary plans switched to become pure investors, but this rate rose to 14.1 percent for existing employees in automatic enrollment plans.

Comparing Columns 3 and 4 also provides another lesson regarding the impact of plan choice architecture on portfolio choice. Specifically, new entrants to voluntary enrollment plans were roughly equally likely to be either pure (14.5 percent) or mixed (13.2 percent) target date fund investors, whereas new entrants to automatic enrollment plans were five times more likely to be pure versus mixed investors (74.9 versus 17.2 percent).[22] One potential explanation for this difference is that employers who defaulted their participants into target date funds under automatic enrollment may have done so anticipating employee preferences for the age-based labeling or age-related rebalancing features unique to target date funds. An alternative explanation, consistent with the household finance literature on inertia and malleable preferences in financial decision-making, is that the default effect is very strong and overrides participant demand for mixed investments.

Our default-related adoption effects across the 880 firms we study are similar in magnitude to prior individual company case studies of automatic enrollment (Madrian and Shea, 2001; Choi, Laibson, Madrian and Metrick, 2004, 2005), where automatically enrolled new entrants remained entirely in the default fund, at rates ranging from 46 to 90 percent. Their results differ from ours due to firm-specific design factors, different methods of measurement, and, in most cases, the fact that their default funds tended to be low-risk money market funds instead of target date funds. Other results on voluntary choice are not directly comparable to ours as these case studies measured the effects of a default fund that had previously been

[22] Both Agnew et al. (2012) and Ameriks et al. (2011) have reported that some participants elect a mixed strategy, believing that this enhances diversification; in other words they fail to recognize that each target date fund is already a highly-diversified multi-asset-class fund. This view may reflect a naïve understanding of diversification or a desire to diversify across multiple managers. Pagliaro and Utkus (2017a) demonstrate how different types of mixed investors diversify their portfolios, including those who alter risk levels and active/passive share.

included in the menu as a voluntary enrollment option, unlike in our setting where we focus on the first appearance of target date funds in the menu. Our measured endorsement effects are meaningfully higher than in previous studies: for example, Benartzi (2001) reported that employees were over 1.5 times more likely to invest their own contributions in employer stock when the employer match to their account was in stock rather than cash (29 versus 18 percent). [23] In our results, the endorsement effect is associated with a two to nearly four times higher propensity to hold target date funds by existing employees, depending on the exact measure. Moreover, the endorsement effect we measure comes from a default designation affecting *employees' co-workers* rather than defaulted employees' own accounts.

We have demonstrated that plan choice architecture clearly has a potent impact on target date use, but other factors correlated with the outcomes are also worth mentioning (for details see Appendix Table 2). Target date adoption was highest among low-balance participants, and it fell for those with larger balances. Younger participants (under age 35) were also more likely to adopt target date funds, either as pure or mixed investors, even after controlling for the effects of new hire auto enrollment. This suggests that workers were either less financially sophisticated or more willing to adopt novel strategies or technologies earlier in their life cycles; hence they found target date funds attractive even aside from their default effects. We also note that target date portfolio choice decisions did not change significantly during the 2008-2009 financial crisis, indicating that the sharp decline in stock prices during the financial crisis did not alter participant demand.

Portfolio Effects from Adoption of Target Date Funds

Having examined how plan architecture influenced retirement savers' portfolios, we next assess how the arrival of target date funds to fund menus shaped adopters' portfolio risk and return characteristics. To this end, we compare pure and mixed target date fund investors with their non-target date fund

[23] Evidence of an 'endorsement effect' resulting from an employer's designation of employer stock as the default for matching contributions has been found by Benartzi (2001), Brown, Liang, and Weisbenner (2007), and Choi, Laibson, and Madrian (2004).

counterparts in terms of equity shares, portfolio return, risk, Sharpe ratios, and nonsystematic or idiosyncratic portfolio risk or variance (reported as a share of total variance, or NSR/TV). We further compare factor risk exposures of each participant subgroup.

As with adoption behavior, we measure several aspects of participants' portfolio allocations one year after the first appearance of target date funds in the plan menu. Equity allocations refer to the fraction of participants' portfolios held in equities in that month.[24] Risk and return characteristics are estimated using a six-factor asset pricing model over the prior 60 months drawing on monthly returns data for plan menu investments over a 17.5 year period (including the 150 month period under analysis, and the preceding five years). For example, if target date funds first appeared in a plan in September 2005, savers' portfolio allocations were observed a year later, in September 2006, and risk and return characteristics were estimated for the 60 months preceding and then predicted for September 2006. Factor returns were calculated using six factors: the market, size, value, and momentum factors for equities, and term and default factors for bonds.[25]

We note that over our January 1998-June 2015 analysis period, the mean equity factor return (the return of the equity market less the risk-free rate) was 5.95 percent (standard deviation of 16.1 percent), while the mean term premium for bonds (the return of long-dated government bonds less the risk-free rate) was 5.41 percent (standard deviation of 10.5 percent). In other words, over the period, the risk premium from equities over long-dated government bonds was small, and long-dated government bonds had a superior Sharpe ratio to equities. Our results should be interpreted in light of how future return and risk characteristics might resemble, or deviate from, these historical data.

[24] Equity share is the percentage of employer and employee contributions directed to U.S. and international equity funds, company stock, and a percentage of balanced and target date funds. The equity percentage for balanced and target date funds is calculated based on each fund's holdings and differs from one target age fund to another.

[25] To calculate portfolio returns over a given 60-month period, we construct a risk-loading matrix for all *k* investment options in a given plan by regressing the excess return (over Treasury bill returns) for each of the *k* assets on the six factors. The factor return for each 401(k) investment option in the predicted month is simply its factor exposure in that month times the average factor returns over the prior 60-month period; the participant's factor return is simply the weighted average return of his or her factor exposures over the period.

Figure 1 summarizes equity share by age for four categories of investors: pure, mixed, non-target date investors, and all participants. Most notable is the higher equity allocation at virtually all ages for pure and mixed target date investors versus non-target date investors. In addition, pure and mixed investors followed a distinctive age-based gradient or glide path, whereas equity shares among non-target date investors followed a hump-shape by age.

Figure 1 here

Table 4 summarizes portfolio characteristics for our three groups of interest and the entire sample. Panel A shows the allocation of total contributions (employer and employee) by major asset class, including cash or principal-guaranteed funds (including money market and guaranteed investment contract funds), bonds, balanced or target date funds (including traditional balanced funds and static allocation or risk-based funds), U.S. equity funds, international equity funds, and employer stock. Panel B indicates equity shares, monthly systematic returns, and portfolio risk, Sharpe ratios, and nonsystematic risk.[26] Panel C summarizes portfolio risk exposures.

Table 4 here

Panel A indicates that non-target date investors held 22.3 percent of their portfolios in cash (i.e., money market instruments and guaranteed investment contracts), while Panel B shows they held an average of 63 percent in equities. By contrast, target date fund investors invested substantially more equity: 80.8 percent for pure investors, and 76.1 percent for mixed investors. This difference produces higher market risk exposures in Panel C: 61.6 percent for non-target date investors, 68.9 percent for pure, and 71 percent for mixed investors. Panel B also indicates that, before controlling on other observables, target date fund

[26] Specifically, $NSR/TV_{i,t} = \hat{\Sigma}_i^{idio} / \hat{\Sigma}_i$. We estimate the variance-covariance matrix for all assets $\hat{\Sigma}$, which in turn is used to estimate the total portfolio variance for the *i*th participant, $\hat{\Sigma}_i$. $\hat{\Sigma} = \hat{\mathrm{B}}' \hat{\Sigma}_f \hat{\mathrm{B}} + \hat{D}$, where $\hat{D}$ is a diagonal matrix with elements computed as the square of the $\hat{\varepsilon}_k$ estimated in equation (2). The asset variance can be decomposed into systematic risk, $\hat{\Sigma}^{sys} = \hat{\mathrm{B}}' \hat{\Sigma}_f \hat{\mathrm{B}}$ and idiosyncratic risk $\hat{D}^{idio}$. Individual portfolio variance is then decomposed into its systematic and idiosyncratic components: $\hat{\Sigma}_i = \omega_{i,k,t}' \hat{\Sigma} \omega_{i,k,t} = \omega_{i,k,t}' (\hat{\Sigma}^{sys} + \hat{D}^{idio}) \omega_{i,k,t} = \hat{\Sigma}_i^{sys} + \hat{\Sigma}_i^{idio}$.

portfolios yielded higher monthly systematic returns (60 to 70 basis points versus 36 basis points for non-target date fund investors), slightly higher monthly volatility (2.8-3.1 versus 2.7 percent), lower monthly Sharpe ratios (13.1-15.5 versus 16.7), and substantially lower idiosyncratic or uncompensated risk (3.6-12.1 versus 25.3 percent). The most notable result in Panel C, besides the market risk increase already reported, are the sharply higher bond market and default premium terms, particularly for pure investors where these exposures doubled (e.g., 0.201 for pure investors versus 0.096 for non-target date investors, for the default premium).

We also seek to determine how these portfolio metrics vary when controlling for observable differences in plan choice architecture and participant characteristics. Accordingly, we estimate a multivariate model of the following form:

$$PORTFOLIO_{i,j,t} = \alpha INVESTORS + \beta PLAN + \gamma PARTICIPANT + v_i + \tau_t + w_j + \varepsilon_{i,j,t} \quad (2)$$

where $PORTFOLIO_{i,j,t}$ is a vector of the five outcome measures of interest—equity share, return, risk, nonsystematic risk and Sharpe ratio—and *INVESTORS* is a matrix representing the type of target date fund investor (pure or mixed, with non-target date as the reference) and type of employee (new entrant, with existing employee as the reference). *PLAN* and *PARTICIPANT* characteristics are also included as above in Equation (1). [27]

Table 5 presents marginal effects for equity share, where Model 1 is as in equation (2), and Model 2 adds age interactions with target date behavior. Results in Model 1 indicate that, on average, pure target date fund adopters held 24 percentage points more equity compared to non-target date investors, whereas mixed target date investors held 13 percentage points more. Model 2 indicates that young pure investors (those under age 35) had an equity share averaging 34 percent points above the reference category, while older pure investors (those over age 55) had an equity share 7 percentage points higher. This implies an increase in the difference of 26 points, underscoring the fundamental feature of target date funds, namely

[27] As in Equation (1), our models also control for plan-level heteroskedasticity (v_i), time fixed effects (τ_t), and industry fixed effects, along with missing data dummies. All models also include a financial crisis control.

their intentional age glide path. By contrast, among non-target date investors, the equity share was only one point higher for young investors and 10 points lower for the older age group, a difference of only 11 points.

Table 5 here

Table 6 presents estimated marginal effects for other portfolio characteristics of interest. Monthly factor returns for pure target date fund investors were 19 basis points per month higher (equivalent to 2.3 percent on an annualized basis), while mixed investors were 14 basis points per month higher (1.7 percent annualized). These are sizeable increases relative to the mean factor return of 44 basis points per month in our dataset (5.4 percent annualized). It is also not surprising that pure (mixed) target date investors experienced larger portfolio standard deviations by 32 (29) basis points, given their higher equity allocations. Interestingly, predicted Sharpe ratios were statistically insignificantly different for target date investors compared to non-target date investors, suggesting that target date adoption moved participants up the efficient frontier compared to non-target date investors, in that they were exposed to more equity, higher expected returns, and more risk. Yet non-target date investors – who principally owned diversified mutual fund portfolios and cash equivalents – were also on the efficient frontier but at a lower risk/return point, as noted in Table 4.[28]

Table 6 here

One other finding from Table 6 is the large impact of target date funds on nonsystematic risk as a percentage of total variance. Idiosyncratic risk overall was around 21 percent of total variance across the entire sample. For pure investors, diversifiable risk was essentially eliminated, with an estimated marginal reduction of 27 percentage points; for mixed investors, it was substantially lower, by 13 percentage points. These results reflect the index nature of the target date funds provided to participants.

Finally, Table 7 compares factor risk exposures across types of participants. Given that plan investment menus were dominated by diversified equity funds prior to the arrival of target date funds, mean market exposure was already 64 percent. Pure (mixed) target date adoption raised this further, by 14 (9)

[28] 80 percent of the assets of all investors were held in low-cost Vanguard mutual funds and trusts, including both active and passive strategies, and the remainder in a range of non-Vanguard funds or trusts.

percentage points. The second most sizeable equity factor was value (HML), at 8 percent; both the pure and mixed target date options raised the value exposure of adopters materially, relative to that 8 percent. Another clear difference is the increase in exposure to bonds among target date versus non-target date investors. For example, pure investors had nearly double the exposure to the default factor (10 percentage point increase on a mean of 12 percent) and the term premium (7 point increase on a mean of 8 percent); similar-sized effects apply to the term factor. Accordingly, target date funds extended participants out the yield curve and boosted their exposure to corporate debt, while materially reducing their cash holdings.[29]

Table 7 here

These changes represent an important change in 401(k) plan participants' portfolio choice: adopters have moved away from the own-portfolio choice approach, to an environment created by the target date fund managers and the employers who hire them. To illustrate the potential benefits of target date adoption, a hypothetical 30-year-old participant earning $35,000 per year and saving 10% of wages would generate retirement wealth of nearly $300,000 over a 30-year period, assuming the mean excess return of 5.4% seen over our time period. At the end of that same period, the retirement nest egg would be an estimated 50 percent higher for pure investors, and one third higher for mixed investors, given a low-cost well-diversified target date series such as that examined here.[30]

We cannot attribute these effects solely to the causal treatment by target date funds, because as previously noted, there may be employer and participant selection effects. For instance, some employers could have introduced the funds or designated them as defaults under automatic enrollment because they felt that participants needed remedial portfolio help – for example, they may have held too much cash, invested too little in bonds, been under-diversified, or failed to rebalance with age. Also, in voluntary enrollment settings, participants could have selected target date funds because of the convenient retirement-

[29] This is consistent with anecdotal observations about inexperienced investors and their relative lack of understanding of, and exposure to, the bond market (a bond market participation problem).

[30] This computation uses the mean return changes for pure and mixed target-date investors, respectively 2.4% and 1.7% annualized, from Table 5. We assumed 1% real wage growth, and importantly no leakage from retirement accounts over the period; the calculations follow the end-of-period convention. Calculations are available from the authors on request.

date labeling which acts as an implicit advice feature, or the convenience of the age-based rebalancing. Nevertheless, we are convinced that target date funds are associated with sizeable shifts in retirement savers' portfolio risk factors and potential increases in future retirement wealth among adopters, relative to non-target date investors. Moreover, as Tang, Mitchell, Mottola, and Utkus (2010) showed, adopters could have "rolled their own" portfolios to mimic the age-relevant target date fund mix using funds available prior to the inclusion of the target date funds on the menu—but chose not to until the introduction of target date funds.

Conclusions and Discussion

Retirement savers in U.S. 401(k) plans have traditionally been responsible for constructing their own retirement investment portfolios, but the advent of target date funds has altered the playing field for workers saving for retirement. We examine 880 retirement plans covering 1.2 million participants to highlight key behavioral mechanisms shaping target date adoption, and in turn, how target date fund adoption has substantively changed portfolio risks and returns among adopters.

We have identified three distinct behavioral effects influencing adoption when target date funds are introduced in either voluntary or automatic enrollment environments. One is an *active choice* effect in voluntary enrollment plans: here, 28.4 percent of new entrants adopted target date funds in their 401(k) portfolios, compared to only 10.2 percent of existing employees. The second is a substantial *default effect* in new hire automatic enrollment plans: 78.7 percent of new entrants in plans with new-hire automatic enrollment adopted target date funds, versus 28.4 percent in voluntary plans. The third is a default-related *endorsement effect:* that is, in new-hire automatic enrollment plans, 21.7 percent of existing employees not subject to auto-enrollment invested in the funds, double the rate of existing employees in voluntary choice plans.

We have also shown that retirement portfolios are dramatically altered when target date funds are adopted in 401(k) plans, as demonstrated by important changes in portfolio risk-taking. For example, pure investors adopting a single fund had a higher equity share (+24 percentage points), a sharper age equity

share gradient (+26 points), and higher factor returns (+2.3% annualized), versus non-target date holders. Besides boosting equity shares for pure and mixed investors, target date funds also produced a distinctive age-based gradient in risk-taking, compared to a hump-shaped equity allocation among non-target date investors. We show that target date participants took on the factor exposures embedded in the target date series offered by fund managers and selected by employers. In our data, that entailed more market risk exposure, greater exposures to term and default premia, and reduced idiosyncratic risk.[31]

These changes are likely to be welfare-enhancing, under the joint assumptions that the target date design represents an efficient portfolio frontier (selected by sponsors and fund managers), and that workers without target date funds would fail to construct efficient portfolios or would select suboptimal points on that frontier due to financial illiteracy and behavioral biases. One illustration of the potential welfare benefits stemming from having higher equity exposure is that pure target date investors in a low-cost broadly diversified target date series could potentially realize up to 50 percent more retirement wealth, relative to non-target date investors. For mixed investors, the wealth increment could be up to 30 percent.

Given these estimates of potential benefits, one might ask what plan sponsors and policymakers might do if they wished to boost target date adoption among existing 401(k) participants. One approach might be to use 'reenrollment,' whereby the plan sponsors could transfer existing employees' investments into age-specific target date funds (or any other default fund), with advance notification to employees and the right to opt out. Reenrollment could lead to similar changes as outlined here for existing non-target date investors.[32] Our results also point to the potential effects of providing low-cost, scalable investment advice more broadly. That is, low-cost lifecycle investment algorithms such as target date funds or robo-advice services[33] could potentially help reduce portfolio construction deficiencies in other settings such as retail investment accounts or personal pensions, possibly reducing the heterogeneity of returns across households (Campbell, Ramadorai, and Ranish, 2019).

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[31] A similar result is reported by Keim and Mitchell (2018) who analyzed target date fund introduction at a single firm.

[32] For more discussion of reenrollment, see Pagliaro and Utkus (2016, 2017b)

[33] See Agnew and Mitchell (2019).

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Table 1. Target Date Fund Characteristics

TDF Fund	Participant Age in 2010	Equity allocation (%)	U.S. stocks (%)	Non-U.S. stocks (%)	U.S. nominal bonds (%)	U.S. inflation-protected bonds (%)	Cash (%)
2055	20	90	63.0	27.0	10.0	0.0	0.0
2050	25	90	63.0	27.0	10.0	0.0	0.0
2045	30	90	63.0	27.0	10.0	0.0	0.0
2040	35	90	63.0	27.0	10.0	0.0	0.0
2035	40	89	62.5	26.8	10.8	0.0	0.0
2030	45	82	57.2	24.5	18.3	0.0	0.0
2025	50	74	52.0	22.3	25.8	0.0	0.0
2020	55	67	46.7	20.0	33.3	0.0	0.0
2015	60	59	41.3	17.7	40.0	1.0	0.0
2010	65	49	34.0	14.6	40.4	10.7	0.4
2005	70	34	24.0	10.3	43.9	17.9	3.9
Income	75	30	21.0	9.0	45.0	20.0	5.0

Note: Fund asset mix measured as of December 2010. Source: Authors' tabulations using Vanguard data; see text.

Table 2. Descriptive Characteristics of Plans and Participants

A. Plan Features and Participant Outcomes (% of accounts)

	All	Pure TDF Investors	Mixed TDF Investors	Non-TDF Investors
Choice architecture features				
TDF Default	52.0	72.1	64.9	46.3
New-hire auto enrollment	32.9	49.5	27.4	30.1
TDF adoption				
TDF investor	24.7	100.0	100.0	0.0
Pure TDF investor	15.7	100.0	0.0	0.0
Mixed TDF investor	9.0	0.0	100.0	0.0
Other plan features				
N Funds offered (mean)	25.6	24.5	24.4	26.0
Employer stock offered	48.4	46.6	53.0	48.3
Loans offered	88.4	88.0	92.8	87.9
N plans	880	852	824	880
N unique accounts	1,262,506	198,242	114,161	950,103

B. Participant Attributes (% of accounts)

	All	Pure TDF Investors	Mixed TDF Investors	Non-TDF Investors
New entrants	19.7	54.5	24.2	11.8
Log account balance (2015$)	9.9	8.1	10.1	10.2
Job tenure (years)	10.0	5.0	8.7	11.3
Young (%<35)	25.1	41.3	28.2	21.4
Middle (% 35-55)	59.6	49.3	59.2	61.9
Old (% >55)	15.2	9.4	12.6	16.8
Male (%)	69.4	65.7	69.3	70.2
Low HH income (% <$62.5K)	31.0	37.9	27.0	30.0
Mid. HH income (% $62.5-$87.5K)	26.7	28.9	26.9	26.2
High HH income (% >$87.5K)	42.3	33.1	46.0	43.7
Low non-ret. fin. wealth (% <$7.3K)	17.9	28.2	17.4	15.9
Mid. non-ret. fin, wealth (% $7.3K-$61.2K)	32.2	39.0	34.2	30.6
High non-ret. fin. wealth (% >$61.2K)	49.9	32.8	48.4	53.6
Financial crisis (% of year)	8.1	8.6	10.1	7.8

Note: Source: Authors' tabulations using Vanguard data; see text and Appendix Table 3.

Table 3. Summary of Predicted Effects of Plan Choice Architecture on Target Date Fund Adoption

In percent	Probability of TDF Adoption (1)	Total Contributions to TDFs (2)	Probability of Pure TDF (3)	Probability of Mixed TDF (4)
Sample mean	24.7	18.9	15.7	9.0
Choice Architecture				
I. Voluntary choice				
A. Existing employees	10.2	7.6	3.9	5.6
B. New entrants	28.4	27.4	14.5	13.2
II. Auto enroll of new entrants to TDF				
A. Existing employees	21.7	18.7	14.1	7.9
B. New entrants	78.7	73.2	74.9	17.2
III. Summary of effects				
Active choice effect (IB v. IA)	2.8	3.6	3.8	2.3
Endorsement effect (IIA v. IA)	2.1	2.5	3.6	1.4
Default effect (IIB v. IB)	2.8	2.7	5.2	1.3

Note: Predicted effects derived from model estimates appearing in Appendix Table 2 (Probit model of probability of adoption; OLS model of total contributions, which includes both employer and employee contributions; and a multinomial Logit model of pure versus mixed versus non-target date adopters), with all other variables held at sample means. 'New entrants' are participants who enrolled with target date funds available in the investment menu; "existing participants" are those who enrolled prior to target date funds being introduced in the menu. Adoption effects are measured one year after first target date fund appearance in menu.
Source: Authors' tabulations using Vanguard data; see text and Appendix Table 3.

Table 4. Contribution Allocations and Portfolio Characteristics of Participants in Plans Adopting Target Date Funds

A. Contribution allocations (%)

	Cash	Bonds	Balanced/ TDF	U.S. Equities	International Equities	Company Stock
All investors	17.3	6.4	29.6	34.3	6.6	5.7
Non TDF investors	22.3	7.7	13.7	41.9	7.7	6.8
Pure TDF investors	0.0	0.0	100.0	0.0	0.0	0.0
Mixed TDF investors	5.9	7.2	39.9	31.1	9.3	6.5

B. Portfolio characteristics (%)

	Equity share	Six-factor CAPM, Predicted Monthly Returns	Monthly Risk (σ)	Sharpe Ratio	NSR/TV
All investors	67.0	0.44	2.75	16.2	20.7
Non TDF investors	63.0	0.36	2.71	16.7	25.3
Pure TDF investors	80.8	0.70	2.77	15.5	3.6
Mixed TDF investors	76.1	0.60	3.07	13.1	12.1

C1. Portfolio risk exposures

	β(Mkt)	β(SMB)	β(HML)	β(UMD)	β(Default)	β(Term)	β(RMSE)
All investors	0.636	-0.011	0.084	-0.008	0.117	0.080	0.010
New entrants	0.621	-0.024	0.086	-0.002	0.150	0.099	0.008
Existing employees	0.640	-0.008	0.083	-0.010	0.109	0.075	0.010
Non TDF investors	0.616	0.001	0.079	-0.011	0.096	0.065	0.010
Pure TDF investors	0.689	-0.073	0.099	0.005	0.201	0.138	0.007
Mixed TDF investors	0.710	-0.006	0.093	-0.005	0.151	0.103	0.011

Note: All of the following β differences are significant at the 1% level: new entrants versus existing employees; pure versus mixed investors; pure versus nontarget date fund; and mixed versus nontarget date fund investors. Source: Authors' computations using Vanguard data; see text and Appendix Table 3 for variable definitions.

Table 5. Marginal Effects of Equity Share and Target Date Treatment

	Mean	Equity Share (1)	Equity Share (2)
TDF investors (%)			
Pure TDF Investors	15.7	0.240 **	0.212 **
Mixed TDF Investors	9.0	0.126 **	0.116 **
Young*Pure TDF Investors (%)	6.5		0.125 **
Old*Pure TDF Investors (%)	1.5		-0.139 **
Young*Mixed TDF Investors (%)	2.6		0.062 **
Old*Mixed TDF Investors (%)	1.1		-0.043 **
Choice architecture			
New-hire auto enrollment (%)	32.9	-0.017	-0.018
New entrants	19.7	-0.016	-0.022
Participant characteristics			
Log balance (mean 2015$)	9.9	0.024 **	0.024 **
Job tenure (years)	10.0	-0.002 **	-0.002 **
Young (% <35)	25.1	0.046 **	0.010 *
Old (% >55)	15.2	-0.117 **	-0.100 **
Male (%)	69.4	0.032 **	0.032 **
HH income low (% <$62.5K)	31.0	-0.026 **	-0.027 **
HH income high (%>$87.5K)	42.3	0.015 **	0.015 **
Wealth low (%<$7.3K)	17.9	-0.028 **	-0.029 **
Wealth high (%>$61.2K)	49.9	0.025 **	0.024 **
Financial crisis (% months)	8.1	-0.012	-0.010
Intercept		0.445 **	0.458 **
Controls		Yes	
Observations		1,262,506	
Number of clusters (plans)		880	
R-squared		0.151	0.158
Mean of dependent variable		67.0%	67.0%

Note: Equity share is percentage of participant contributions direct to stock market investments. Controls include plan-level controls for number of funds, employer stock, and loans offered. Standard errors clustered at the plan level. * Significant at 5%, *** significant at 1%. Source: Authors' computations using Vanguard data; see text and Appendix Table 3 for variable definitions.

Table 6. Marginal Effects of Portfolio Outcomes and Target Date Treatment

	Mean	Monthly Return	Monthly Risk (σ)	Sharpe Ratio	NSR/TV
TDF investors (%)					
Pure TDF Investors	15.7	0.0019 *	0.0032 **	-0.0687	-0.2703 **
Mixed TDF Investors	9.0	0.0014 *	0.0029 **	-0.0348	-0.1344 **
Choice architecture					
New-hire auto enrollment (%)	32.9	-0.0014	-0.0010	-0.0722	0.0051
New entrants	19.7	-0.0006	-0.0012 **	-0.0209	0.0225
Participant characteristics					
Log balance (mean 2015$)	9.9	0.0004	0.0008 **	-0.0015	-0.0165 **
Job tenure (years)	10.0	0.0000	-0.0001 **	0.0022 **	0.0015 **
Young (% <35)	25.1	0.0002	0.0013 **	-0.0079	-0.0019
Old (% >55)	15.2	-0.0006	-0.0041 **	0.0401 **	0.0440 **
Male (%)	69.4	0.0003	0.0013 **	0.0089	-0.0033
HH income low (% <$62.5K)	31.0	-0.0004 **	-0.0011 **	0.0028	0.0182 **
HH income high (%>$87.5K)	42.3	-0.0001	0.0005 **	-0.0111 *	-0.0080 **
Wealth low (%<$7.3K)	17.9	0.0001	-0.0009 **	0.0250 *	0.0224 **
Wealth high (%>$61.2K)	49.9	-0.0002	0.0009 **	-0.0182 **	-0.0148 **
Financial crisis (% months)	8.1	-0.0528 **	0.0006	-1.3855 **	0.0385 *
Intercept		0.0320 **	0.0286 **	1.0203 **	0.3548 **
Controls			Yes		
Observations			1,262,506		
Number of clusters (plans)			880		
R-squared		0.514	0.247	0.447	0.179
Mean of dependent variable		0.0044	0.0275	0.1621	0.2069

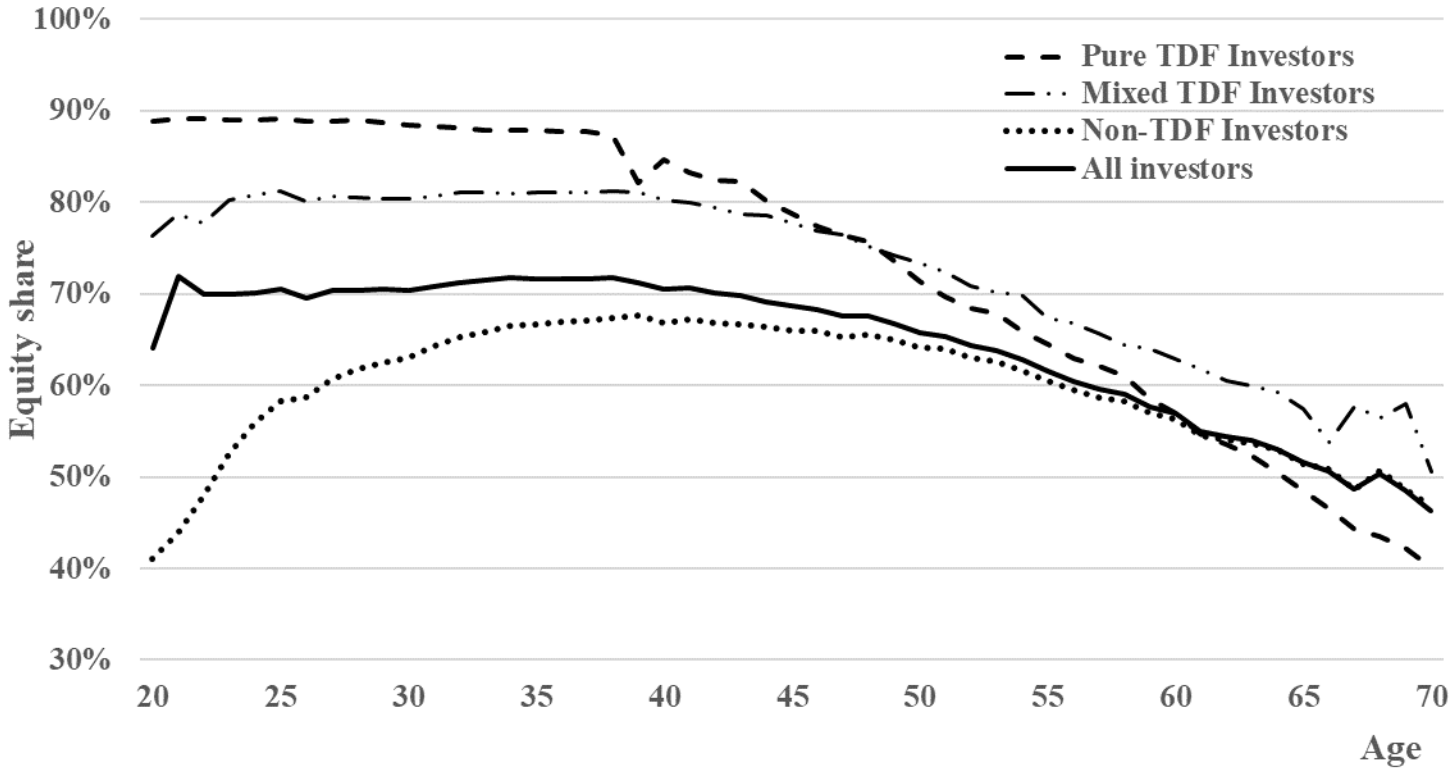
Note: See text for definition of dependent variables. Controls include plan-level controls for number of funds, employer stock and loans offered. Standard errors clustered at the plan level. * Significant at 5%, ** significant at 1%. Source: Authors' computations using Vanguard data; see text and Appendix Table 3 for variable definitions.

Table 7. Marginal Effects of Portfolio Risk Exposures and Target Date Treatment

	Mean	β(Mkt)	β(SMB)	β(HML)	β(UMD)	β(Default)	β(Term)	β(RMSE)
TDF investors (%)								
Pure TDF Investors	15.7	0.135 **	-0.084 **	0.026 **	0.012 **	0.101 **	0.072 **	-0.002 **
Mixed TDF Investors	9.0	0.090 **	-0.015 **	0.013 **	0.004 **	0.050 **	0.040 **	0.001 *
Choice architecture								
New-hire auto enrollment (%)	32.9	-0.018	-0.002	-0.011 *	0.002	-0.008	-0.005	-0.001 *
New entrants	19.7	-0.015	0.014 **	0.000	0.003 **	0.001	-0.003	0.000
Participant characteristics								
Log balance (mean 2015$)	9.9	0.022 **	0.003 **	0.002 **	0.000	0.002 **	0.000	0.000 **
Job tenure (years)	10.0	-0.002 **	-0.001 **	0.000	0.000 *	-0.001 **	-0.001 **	0.000 *
Young (% <35)	25.1	0.032 **	0.005 **	0.011 **	0.003 **	0.011 **	-0.007 **	0.001 **
Old (% >55)	15.2	-0.100 **	-0.009 **	-0.013 **	-0.001 **	-0.010 **	0.012 **	-0.001 **
Male (%)	69.4	0.028 **	0.006 **	0.001	0.000	0.002	-0.004 **	0.001 **
HH income low (% <$62.5K)	31.0	-0.026 **	-0.003 **	-0.003 **	0.000	-0.003 **	-0.001 *	0.000 **
HH income high (%>$87.5K)	42.3	0.015 **	0.004 **	0.002 **	0.000	0.002 **	0.001	0.000 **
Wealth low (%<$7.3K)	17.9	-0.028 **	-0.002 **	-0.001	0.000	-0.003 *	-0.001 *	0.000 **
Wealth high (%>$61.2K)	49.9	0.024 **	0.003 **	0.000	0.000	0.001	0.000	0.000 **
Financial crisis (% months)	8.1	-0.004	-0.005	0.013	0.003	0.003	0.004	0.001
Intercept		0.451 **	-0.048 **	0.065 **	-0.022 **	0.027 *	0.053 **	0.007 **
Controls					Yes			
Observations					1,262,506			
Number of clusters (plans)					880			
R-squared		0.111	0.140	0.098	0.111	0.247	0.151	0.151
Mean of dependent variable		0.636	-0.011	0.084	-0.008	0.117	0.080	0.010

Note: See text for definition of dependent variables. Controls include plan-level controls for number of funds, employer stock and loans offered. Standard errors clustered at the plan level. * Significant at 5%, ** significant at 1%. Source: Authors' computations using Vanguard data; see text and Appendix Table 3 for variable definitions.

Figure 1. Equity Share by Age and Investor Type



Source: Authors' calculations.

Appendix Table 1. Year-by-Year Target Date Fund Adoption Patterns and Other Trends

	By Year												Entire Period
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2003-2014
Default architecture													
TDFDefault (%)	0.0	8.0	14.9	29.1	70.5	84.6	66.9	93.5	80.7	80.3	14.7	72.1	52.0
New-hire auto enrollment (%)	0.0	0.1	26.5	43.2	38.1	37.7	35.5	45.2	31.9	2.8	11.6	36.2	32.9
New entrant (%)	16.1	13.9	22.6	18.2	26.7	13.1	9.1	12.1	22.2	14.5	11.9	15.8	19.7
Other plan characteristics													
N funds offered (mean)	69.2	38.5	19.0	22.7	25.8	24.7	27.1	28.5	24.4	29.1	28.9	23.5	25.6
Employer stock offered (%)	0.0	7.4	58.7	45.3	56.3	54.0	51.5	14.2	0.0	0.0	84.0	0.0	48.4
Loan offered (%)	3.5	56.7	88.7	96.1	94.1	83.8	91.2	98.8	92.7	76.8	97.1	95.8	88.4
SA enabled (%)	100.0	60.9	28.8	32.3	63.3	74.0	86.3	81.9	87.7	79.0	11.9	70.4	55.4
Participant characteristics													
Log balance (mean 2015$)	10.1	9.8	10.0	9.9	9.5	10.1	10.3	10.2	9.4	10.4	11.4	9.1	9.9
Job tenure (years)	4.6	8.2	11.5	8.8	9.5	11.0	13.0	10.7	8.8	8.9	12.2	9.7	10.0
Young (<35, %)	26.4	26.2	23.2	26.5	25.7	25.6	21.4	23.0	23.1	24.7	23.1	22.8	25.1
Middle (35-55, %)	62.3	60.5	61.5	59.3	60.7	57.8	57.3	58.3	57.6	59.0	54.3	53.2	59.6
Old (>55, %)	11.3	13.3	15.3	14.3	13.6	16.5	21.3	18.7	19.3	16.3	22.6	24.1	15.2
Male (%)	30.9	62.6	59.4	72.6	75.6	65.2	71.3	77.9	64.1	60.6	79.6	69.1	69.4
HH income low (<$62.5K, %)	22.0	27.3	33.1	33.8	32.1	29.5	29.2	28.5	32.9	27.3	21.4	19.1	31.0
HH income medium ($62.5-$87.5K, %)	22.6	26.1	29.3	25.0	26.9	26.2	27.1	26.2	33.9	27.5	22.6	33.7	26.7
HH income high (>$87.5K)	55.4	46.5	37.6	41.2	41.0	44.2	43.7	45.3	33.2	45.2	56.0	47.2	42.3
Low (<$7.3K, %)	3.4	9.1	15.5	19.7	19.7	18.1	18.8	18.9	33.7	20.8	18.7	21.6	17.9
Average ($7.3K-$61.2K, %)	16.4	23.0	31.9	31.3	34.9	33.2	35.9	32.3	31.3	29.8	26.7	32.4	32.2
High (>$61.2K, %)	80.3	67.9	52.6	49.0	45.4	48.7	45.3	48.8	35.0	49.4	54.6	46.1	49.9
Financial Crisis													
Financial crisis (% of year)	0	0	0	0	0	1/3	1/3	0	0	0	0	0	8.1
TDF adoption (% of accounts)													
TDF investor	1.7	10.1	19.5	25.4	26.5	29.0	21.2	40.3	51.2	50.5	12.2	37.4	24.7
Pure TDF investor	1.1	6.8	11.3	16.4	18.0	16.5	13.0	24.1	35.8	40.4	5.8	22.2	15.7
Mixed TDF investor	0.6	3.3	8.2	9.0	8.5	12.5	8.2	16.2	15.4	10.1	6.4	15.2	9.0
Observations													
N plans	6	93	109	157	168	129	63	48	43	27	22	15	880
N accounts	11,310	87,514	189,648	204,932	403,984	208,196	46,046	42,177	8,224	19,282	37,172	4,021	1,262,506

Source: Authors' computations using Vanguard data; see text and Appendix Table 3 for variable definitions.

Appendix Table 2. Estimated Determinants of Participant Target Date Fund Adoption Patterns

	Mean	Probability of TDF adoption (Probit marginal effects) (1)	Contributions to TDFs (OLS coefficients and standard errors) (2)		Prob. of Pure Investor (Mult. Logit marginal effects) (3)	Prob. of Mixed Investor (Mult. Logit marginal effects) (4)
Choice architecture features						
TDFDefault (%)	52.0	15.4 ***	0.100 ***	0.018	9.0 ***	7.7 ***
New-hire auto enrollment (%)	32.9	-1.6	0.011	0.023	3.8 *	-4.4 **
New entrant (%)	19.7	23.0 ***	0.199 ***	0.026	18.3 ***	9.7 ***
New-hire auto enrollment*New entrant (%)	8.6	4.0	-0.034	0.087	-2.8	9.6 ***
New-hire auto enrollment*New entrant*TDFDefault (%)	5.6	25.9 ***	0.381 ***	0.095	28.7 ***	-5.5 ***
Participant characteristics						
Log balance (mean 2015$)	9.9	-1.8 ***	-0.017 ***	0.002	-1.9 ***	1.2 ***
Job tenure (years)	10.0	-0.4 ***	-0.003 ***	0.001	-0.4 ***	-0.2 ***
Young (<35, %)	25.1	3.5 ***	0.029 ***	0.007	2.0 ***	1.8 ***
Old (>55, %)	15.2	-0.8	0.004	0.004	0.3	-1.1 ***
Male (%)	69.4	1.2	0.010	0.010	0.6	0.6
HH income low (<$62.5K, %)	31.0	-0.6	0.002	0.004	0.4	-1.1 ***
HH income high (>$87.5K, %)	42.3	-0.3	-0.004	0.004	-0.7 *	0.1
Wealth low (<$7.3K, %)	17.9	1.0	0.014 **	0.006	0.8 **	-0.1
Wealth high (>$61.2K, %)	49.9	-1.7 ***	-0.013 ***	0.005	-1.6 ***	-0.6 *
Financial crisis (%)	8.1	-4.1	-0.034	0.030	-2.8	-1.0
Intercept			0.348 ***	0.079		
Controls			Yes			
Observations			1,262,506			
Number of clusters (plans)			880			
-2LogL		1,129,377	N/A		1,438,045	
Pseudo-R squared / R-squared		0.201	0.283		0.263	
Mean of dependent variable		24.7%	18.9%		15.7%	9.0%

Source: Probit model of probability of adoption; OLS model of total contributions, which includes both employer and employee contributions; and a multinomial logit model of pure versus mixed versus non-target date adopters. 'New entrants' are participants who enrolled with target date funds available in the investment menu; "existing participants" are those who enrolled prior to target date funds being introduced in the menu. Adoption effects are measured one year after first target date fund appearance in menu. Source: Authors' computations using Vanguard data; see text and Appendix Table 3 for variable definitions.

Appendix Table 3. Variable Descriptions

Variable	Description
TDF adoption (0/1)	=1 if employee contributes to TDF funds, 0 else
Contributions to TDFs (%)	Percentage of monthly contribution invested into TDF funds
Pure TDF Investors	=1 if employee only contributes to TDF funds, 0 else
Mixed TDF Investors	=1 if employee contributes to TDF and non-TDF funds, 0 else
Equity Allocations (%)	Percentage of monthly contribution invested into equity assets
Monthly return (%)	Monthly predicted factor return
Monthly Standard deviation (σ) (%)	Monthly predicted standard deviation of factor return
Nonsystematic risk/total variance (NSR/TV) (%)	Ratio of non-sysmatic risk of total portfolio variance
Sharpe Ratio	Ratio of monthly predicted factor return to monthly predicted standard deviation
β(Mkt)	Weighted estimated coefficient of benchmark Mkt
β(SMB)	Weighted estimated coefficient of benchmark SMB
β(HML)	Weighted estimated coefficient of benchmark HML
β(UMD)	Weighted estimated coefficient of benchmark UMD
β(Defaultprem)	Weighted estimated coefficient of benchmark Defaultprem
β(Termprem)	Weighted estimated coefficient of benchmark Termprem
β(RMSE)	Weighted estimated Root MSE
Default	=1 if TDF fund as default in plan, 0 else
New entrants	=1 if employee began contribution after TDF introduction, = else
New-hire auto enrollment	=1 if the month is after Vanguard TDF auto enrollment date; =0 else
N Funds offered	# funds offered in plan
Employer stock offered	=1 if plan offers company stock; =0 else
Loan offered	=1 if plan offers loan; =0 else
Log balance (mean 2015$)	Natural logarithm of balance in 2015$
Job tenure (years)	Years of job tenure
Young (age<35)	=1 if employee's age<35, =0 else
Old (age>55)	=1 if employee's age>55, =0 else
Male	=1 if employee is male, = 0 else
HH income low (<$62.5K)	=1 if HH income<$62,500, =0 else
HH income high (>$87.5K)	=1 if HH income>87,500, =0 else
Wealth low (<$7.3K)	=1 if HH wealth<$7.3k, =0 else
Wealth high (>$61.2K)	=1 if HH wealth>$61.2k; =0 else
Financial crisis	=1 if month is between 200809 and 200903, =0 else