BEYOND THE STATUS QUO: A CRITICAL ASSESSMENT OF LIFECYCLE INVESTMENT ADVICE

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Abstract

We challenge two central tenets of lifecycle investing: (i) investors should diversify across stocks and bonds and (ii) the young should hold more stocks than the old. An even mix of 50% domestic stocks and 50% international stocks held throughout one's lifetime vastly outperforms age-based, stock-bond strategies in building wealth, supporting retirement consumption, preserving capital, and generating bequests. These findings are based on a lifecycle model that features dynamic processes for labor earnings, Social Security benefits, and mortality and captures the salient time-series and cross-sectional properties of long-horizon asset class returns. Given the sheer magnitude of US retirement savings, we estimate that Americans could realize trillions of dollars in welfare gains by adopting the all-equity strategy.

JEL classifications: C15, D14, G11, G17, G51
Key words: Retirement, retirement savings, target-date funds, survivor bias, easy data bias

1 Introduction

Every year, Americans contribute about 5% of their total employee compensation to defined contribution (DC) pension plans, totaling \$586 billion in 2020 alone.[1] They then face a question that determines their financial fate: How should I invest my savings? Many consult financial advisors. These professionals impart two central tenets of lifecycle investing — people should diversify across stocks and bonds and the young should invest more heavily in stocks than the old — perhaps having learned them from investments textbooks [e.g., Bodie, Kane, and Marcus (2024)] or CFA study materials [e.g., Blanchett, Cordell, Finke, and Idzorek (2023)]. Other savers seek answers on their own, reading a popular book by Dave Ramsey, Suze Orman, or Tony Robbins. They receive similar advice [Choi (2022)]. Finance professors managing their own portfolios may closely study the theoretical literature on lifecycle investing and reach the same conclusions [e.g., Viceira (2001); Campbell and Viceira (2002); and Cocco, Gomes, and Maenhout (2005)]. A great many others either are disinterested in the investment process or have no financial knowledge, so they simply invest in the default option of their employer's retirement plan. To safeguard these investors, the Pension Protection Act of 2006 (PPA) created safe harbors for employers with respect to default options in DC plans. The most popular type of Qualified Default Investment Alternative (QDIA) is a portfolio that provides "long-term appreciation and capital preservation through a mix of equity and fixed income exposures based on the participant's age," [29 CFR § 2550.404c-5(e)(4)(i)].[2] As such, regulators rely on "generally accepted investment theories" [29 CFR § 2550.404c-5(e)(4)] that mirror the two principles to define QDIAs. In summary, these pieces of investment advice — split investments across stocks and bonds and invest more in stocks while young than while old — are close to being uniformly given and universally followed.

In this paper, we challenge these two tenets of lifecycle investing. We assess the performance of several QDIAs, including a representative target-date fund (TDF) strategy along with other balanced and age-based stock-bond strategies, in providing long-term appreciation and capital preservation for retirement savers. We adopt a block bootstrap simulation approach within a lifecycle model with labor income uncertainty, Social Security income, and longevity risk. We emphasize the need to maintain the time-series and cross-sectional properties of stock and bond returns that show through in the data. Studying lifecycle portfolio choice with long-horizon returns

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[1] The total DC plan contribution is from the 2022 Private Pension Plan Bulletin from the Department of Labor. The 5% figure divides \$586 billion in 2020 DC contributions by \$11,593 billion in 2020 compensation of employees from Table 2.1 of the national income and product accounts (NIPA) from the Bureau of Economic Analysis.

[2] See `https://www.law.cornell.edu/cfr/text/29/2550.404c-5`. Vanguard (2023) reports that target-date funds, which are QDIAs under 29 CFR § 2550.404c-5(e)(4)(i), make up 98% of the QDIAs in DC plans.

rather than relying on short-horizon (e.g., monthly or annual) return moments is crucial given serial dependencies in returns and the long-term nature of retirement saving. As some people's lifetime investment periods stretch for 75 years or longer, the relatively short history of US financial markets presents an extreme small sample problem for long-horizon returns. To combat this problem, our bootstrap simulation uses a comprehensive dataset of returns on domestic stocks, international stocks, bonds, and bills that spans 38 developed countries and nearly 2,500 years of country-month return data from Anarkulova, Cederburg, and O'Doherty (2023). We evaluate strategies based on four retiree outcomes: wealth at retirement, retirement income, conservation of savings, and bequest at death.

We find that a simple, all-equity portfolio outperforms QDIAs across all retirement outcomes. A strategy of investing 50% in domestic stocks and 50% in international stocks throughout one's lifetime — which is not a QDIA — dominates the QDIAs in long-term appreciation by generating more wealth at retirement and providing higher initial retirement consumption. Surprisingly, the all-equity strategy also compares favorably with the QDIAs in capital preservation. Households allocating 50% to domestic stocks and 50% to international stocks are less likely to exhaust their savings and more likely to leave a large inheritance. This non-QDIA strategy beats the TDF and other QDIAs across the board in achieving the PPA goals of long-term appreciation and capital preservation.

Our bootstrap simulation follows the lifecycle of a US couple (a female and a male) who saves during working years and consumes during retirement years. They first adopt a lifetime portfolio strategy to invest for retirement. The couple then begins to save a portion of their monthly income at age 25, and we model their uncertain labor income using the age-based, heterogenous earnings model of Guvenen, Karahan, Ozkan, and Song (2021). At age 65, the couple retires. They begin to receive Social Security income and draw down on savings with constant real withdrawals using the popular 4% rule.[3] They continue to invest any remaining wealth during retirement. Simulated investment outcomes are based on historical developed country asset-class returns and the couple's portfolio weights. The female and male have uncertain longevity, which we model using the Social Security Administration (SSA) mortality tables, and the couple leaves an inheritance upon the passing of the last remaining spouse.

We focus our discussion here on four asset allocation strategies: a representative TDF strategy, a 100% government bills strategy that mimics a money market fund, a 100% domestic stocks strategy,

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[3] The 4% rule dictates that the couple withdraws 4% of their initial retirement wealth balance in the first year and then withdraws equal inflation-adjusted amounts in subsequent years. The 4% rule is ubiquitous in financial advice on retirement spending [see Anarkulova, Cederburg, O'Doherty, and Sias (2023) and cites therein].

and a 50% domestic stocks and 50% international stocks strategy. TDFs follow age-based strategies that diversify across equity and fixed income investments according to lifecycle glidepath portfolio weights. The TDF strategy we consider, which uses weights from a large investment management firm, achieves similar outcomes to four additional QDIAs we study. Money market and stable value funds were common default options in employer DC plans prior to the PPA, so we include the 100% bills strategy to provide a pre-QDIA benchmark.[4] Both all-equity strategies aggressively pursue the high average returns on equity compared with fixed income.

A comparison of the performance of the TDF versus bills illustrates the welfare gains generated by the PPA. Relative to bills, the TDF produces more wealth at retirement, higher retirement consumption, a lower probability of financial ruin (defined as the depletion of financial wealth before death), and larger bequest. The gains achieved by QDIAs relative to the status quo ante of money market and stable value funds are particularly important for those who invest in the default options of their employer's DC plan.

We also compare the TDF to the two non-QDIA, all-equity strategies. For the most part, these strategies outperform the TDF in long-term appreciation, capitalizing on the high average return of stocks. The Stocks strategy, which invests 100% in domestic stocks throughout the lifecycle, generates 30% higher average retirement wealth than the TDF, and the Stocks/I strategy, which allocates 50% to domestic stocks and 50% to international stocks, produces 32% higher average retirement wealth. The Stocks strategy does have worse left-tail outcomes than the TDF. The internationally diversified Stocks/I strategy, in contrast, is favored relative to the TDF throughout the entire distribution of wealth outcomes. Stocks/I also dominates the TDF in retirement consumption levels, because wealthier people can spend more.

TDFs shift away from equity and towards fixed income as investors age with the aim of preserving wealth, whereas the Stocks and Stocks/I strategies maintain constant allocations. Retired couples using the TDF have a 16.9% ruin probability, which is lower than the 17.4% ruin probability for Stocks. Surprisingly, the all-equity Stocks/I strategy dominates the TDF in capital preservation. Stocks/I has a ruin probability of 8.2%, less than half of that of the TDF. Stocks/I also provides much larger bequests compared with the TDF. In sum, Stocks/I dominates the TDF in all four outcomes related to long-term appreciation and capital preservation.

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[4] In 2005, 60% of employer plans had money market or stable value funds as the default investment option, and 42% of single-fund investors held these funds [Vanguard (2014)]. Employees who are automatically enrolled in retirement plans are particularly likely to default into a fund. Madrian and Shea (2001) demonstrate that 75% of new workers in a large company that switched to automatic enrollment in 401(k) plans kept their entire balance in the default money market fund, and Choi, Laibson, and Madrian (2004) show most of these workers' default allocations persisted for years.

We introduce utility from retirement consumption and bequest to measure the economic magnitude of differences in strategy performance. To achieve the same retirement-period utility as a couple who is willing to invest 10.0% of their income in the Stocks/I strategy, a couple investing in the TDF would need to save 14.1% of their income. This additional savings burden along with the sheer magnitude of the \$586 billion in 2020 DC contributions implies an aggregate welfare cost for US investors of \$240 billion per year [= \$586 billion × $(0.141/0.100 - 1)$] from investing in the TDF rather than Stocks/I.

The preceding discussion glosses over a difference in intermediate retirement account performance between the TDF and Stocks/I strategies. Despite the fact that Stocks/I dominates the TDF in each retirement outcome, Stocks/I often has a larger intermediate drawdown (i.e., a larger peak-to-trough decline in asset value) than the TDF. Concentrating on the largest real drawdown during the couple's retirement period, Stocks/I averages 50% whereas the TDF strategy averages 38%. Regulations stipulate that QDIAs be "diversified so as to minimize the risk of large losses" [29 CFR § 2550.404c-5(e)(4)], and the Department of Labor and the Securities and Exchange Commission held a joint hearing in 2009 to discuss large TDF losses resulting from the market crash in 2008 [Camillo, Robertson, Ziga, Paulson Egbert, and Patel (2009)]. As such, minimizing intermediate drawdowns appears to be a priority for regulators regardless of retirement outcomes. An important policy issue is the extent to which regulation should focus on minimizing the psychological pain of intermediate drawdowns versus maximizing the economic outcomes of retirement savers given the vast performance disparities across strategies.

We find that Stocks/I dominates despite its violation of the central tenets of lifecycle investing that investors should diversify across stocks and bonds and use age-based strategies. Two aspects of our methods matter for strategy evaluation. First, our simulation approach maintains time-series and cross-sectional dependencies in asset class returns. We specifically employ a stationary block bootstrap [Politis and Romano (1994)] with a long average block length of 120 months to preserve long-term return dependencies. This technique contrasts with the common approaches of assuming independent and identically distributed (IID) returns or relying on moments of short-term (e.g., monthly or annual) returns to study lifecycle investing. Second, we use a comprehensive dataset of developed country returns to overcome the small sample problem posed by US data. We find that a bootstrap simulation that uses US return data and assumes IID returns generates a sharply different conclusion about retirement saving. Under the US-IID method, age-based strategies that diversify across stocks and bonds appear favorable relative to Stocks/I for retirement savers for whom capital preservation in retirement is important. Moving away from either of these two assumptions — i.e., acknowledging that returns are not IID *or* that the US sample presents a severe small sample problem for long-horizon asset performance — restores our conclusion that Stocks/I dominates.

Our study is related to the literature on lifecycle investment strategies. Choi and Robertson (2020) survey a representative sample of US investors and report that "time left until their retirement" is the strongest determinant of the percentage of financial assets held in stocks. These responses are generally consistent with the empirical evidence on the lifecycle profile of risky asset share [see, e.g., Poterba and Samwick (1997); Fagereng, Gottlieb, and Guiso (2017); and Parker, Schoar, and Sun (2022)]. A large literature on lifecycle portfolio choice attempts to explain these patterns in stock holdings using lifecycle models with unspanned risky labor income [e.g., Cocco, Gomes, and Maenhout (2005)], medical expenditure risk [e.g., Yogo (2016)], and a wide range of other economic features.[5] We contribute to this literature by documenting a large wedge between observed and optimal investor behavior, and our results speak to the importance of addressing small sample problems and accounting for time-series dependencies in returns in calibrating lifecylce portfolio choice models.

We also contribute to a growing literature on the performance of TDFs and other popular retirement saving strategies. Dahlquist, Setty, and Vestman (2018) and Duarte, Fonseca, Goodman, and Parker (2022) compute optimal decision rules in lifecycle models and estimate large welfare losses from constraining investors to follow homogeneous age-based asset allocation rules. The latter study emphasizes the potential for improvements in portfolio construction from conditioning on investor wealth, the state of the business cycle, and equity valuation levels. Several recent studies [e.g., Michaelides and Zhang (2017); Kraft, Munk, and Weiss (2019); Michaelides and Zhang (2022); and Gomes, Michaelides, and Zhang (2022)] build on an earlier literature on portfolio choice under time-varying expected returns [e.g., Barberis (2000), Xia (2001), and Pástor and Stambaugh (2012)] and also document large welfare gains from modifying TDF asset allocation policies to exploit stock return predictability. Much of this prior work in the normative literature on portfolio choice in retirement saving attempts to characterize the welfare losses from constraining investors to adopt TDF or age-based investment policies vis-à-vis their optimal portfolio allocations. The results are insightful on the limitations of existing strategies and the dimensions on which these strategies might be improved. There are, however, practical limitations on the level of customization that can be offered within DC retirement plans owing to both legal factors and investor sophistication.

Recent review articles by Choi (2022) and Cochrane (2022) note the large gap between normative portfolio theory and practice and call for wider applications of portfolio theory that are

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[5] Gomes, Haliassos, and Ramadorai (2021) provide a comprehensive survey of this literature.

accessible and useful to investors. We follow this approach and find that, relative to traditional balanced strategies, TDF strategies, and other age-based investment strategies, a simple asset allocation rule that diversifies across domestic and international stocks with constant portfolio weights yields economically large improvements in retirement wealth accumulation, income replacement in retirement, bequests, and retirement utility. Our findings build on important prior work by Poterba, Rauh, Venti, and Wise (2005, 2009); Arnott (2012); and Estrada (2014) on pre-retirement wealth accumulation under different investment strategies. Relative to these prior studies, we incorporate substantial improvements in the modeling of asset class returns and stochastic labor income. More important, we evaluate a wide range of alternative investment policies with a comprehensive set of retirement outcomes that depend on both pre- and post-retirement investment performance. As such, our results speak more broadly to the lifecycle allocation problem faced by households. Our findings should be of interest to regulators in defining QDIA-eligible strategies, investment management companies in retirement fund design, and plan sponsors and participants in fund selection.

2 Asset allocation strategies

We compare household retirement saving outcomes under eight alternative investment strategies. Each strategy specifies weights for domestic stocks, international stocks, bonds, and bills. Some strategies have constant weights, whereas others specify weights as a function of investor age. Table I describes the strategies and introduces the reference notation used in subsequent exhibits.

The five strategies presented in Panel A of Table I are safe harbor default investment options (i.e., QDIAs) under the PPA. These strategies are designed to provide both long-term appreciation and capital preservation by allocating across equity and fixed income asset classes. Each investment strategy either adjusts its asset allocation over time "with the objective of becoming more conservative (i.e., decreasing risk of losses) with increasing age" or maintains an asset allocation that is "consistent with a target level of risk appropriate for participants of the plan as a whole," [29 CFR § 2550.404c-5(e)(4)]. In addition to their preferred status under current pension regulations, these strategies have strong underpinnings in finance theory and practical investment advice.

The first strategy shown in Panel A of Table I follows the advertised unconditional glidepath from a TDF offered by a major investment firm. The glidepath weights in domestic stocks, international stocks, bonds, and bills are shown in Figure 1. As with other TDFs, the specific strategy that we consider follows an age-based asset allocation policy. The fund adopts an aggressive allocation with higher exposure to equities for a younger investor to facilitate wealth accumulation. The strategy gradually becomes more conservative with increased exposure to fixed income assets as the investor's retirement date approaches and becomes increasingly conservative through the retirement period.

From a theoretical perspective, the TDF strategy's decline in equity share over the lifecycle can be justified by arguments that the present value of bond-like labor income declines with age [see, e.g., Viceira (2001); Campbell and Viceira (2002); and Cocco, Gomes, and Maenhout (2005)], that labor supply flexibility declines with age [see, e.g., Bodie, Merton, and Samuelson (1992)], and that mean reversion in returns makes stocks more attractive for long-horizon investors [see, e.g., Barberis (2000), Wachter (2002) and Siegel (2014)]. From a practical perspective, TDFs offer diversification benefits and automatic reallocation features that may protect investors from the adverse effects of behavioral biases and financial illiteracy in portfolio construction.[6] TDFs have exploded in popularity since the passage of the PPA, with total assets under management (AUM) growing from \$114 billion in 2007 to \$1.8 trillion in 2021 [Investment Company Institute (2022)].[7] This growth reflects the aggressive trend of plan sponsors' adoption of automatic enrollment features, the overwhelming tendency to select TDFs as default funds, and the propensity for participants to retain the default elections [see, e.g., Madrian and Shea (2001) and Mitchell and Utkus (2022)]. Across all participants in Vanguard plans, for example, 83% use TDFs and 59% hold their entire account balance in a single TDF [Vanguard (2023)].

The second and third strategies shown in Panel A are balanced strategies with fixed asset class weights of 60% in stocks and 40% in bonds. The Balanced strategy invests solely in domestic stocks and bonds and is consistent with the empirically observed home bias in asset holdings [see, e.g., French and Poterba (1991)]. The Balanced/I strategy incorporates international equity diversification by splitting the stock allocation equally across domestic and international stocks. This equal split of the equity share provides a simple rule of thumb for investors and falls at the high end of the recommended level of international diversification in the personal finance books surveyed

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[6] There is a large literature on the roles of behavioral biases and financial illiteracy in retirement savings. For example, these factors are known to have adverse effects on decisions related to international diversification [Bekaert, Hoyem, Hu, and Ravina (2017)], asset allocation [Benartzi and Thaler (2001)], contribution levels [Lusardi and Mitchell (2007, 2011) and Goda, Levy, Manchester, Sojourner, and Tasoff (2020)], stock market participation [van Rooij, Lusardi, and Alessie (2011)], and account concentration in employer stock [Poterba (2003)]. Campbell (2016), Beshears, Choi, Laibson, and Madrian (2018), and Gomes, Haliassos, and Ramadorai (2021) provide comprehensive reviews of this evidence.

[7] These estimates correspond to mutual fund assets held in TDFs. The aggregate AUM for target-date strategies across mutual funds and collective investment trusts (CITs) at year-end 2021 is \$3.3 trillion [see, e.g., Pacholok and Zaya (2023)].

by Choi (2022). From the perspective of US investors, the equal equity allocation across domestic and international markets is also roughly in line with global equity market weights.[8] Although the balanced strategies have safe harbor status under the PPA, they are far less popular relative to TDFs. Just 2% of Vanguard plans with a QDIA choose a balanced fund as the default, and fewer than 1% of participants are solely invested in a single balanced fund [Vanguard (2023)].

The final two QDIA strategies in Panel A follow the "120−Age" rule, which specifies an allocation of (120−Age)% in stocks and the remainder in bonds. The "120−Age" rule shares its theoretical underpinnings with the TDF strategy, but it represents a somewhat simpler investment heuristic that is popular among financial advisors. In Choi's (2022) survey of the 50 most popular books on personal finance, for example, he finds that nine explicitly recommend an asset allocation that is a decreasing linear function of investor age. As with the balanced strategies in Panel A, we consider versions of the "120−Age" rule with stock allocations that are fully domestic (Age) or diversified across domestic and international markets (Age/I).

The strategy detailed in Panel B of Table I is a pure capital preservation strategy that specifies a 100% allocation to bills. This strategy mirrors the performance of the money market and stable value funds that were popular defaults in the pre-PPA period.

Panel C of Table I shows two equity strategies, neither of which is a QDIA. The first is a simple allocation of 100% to domestic stocks (Stocks). This strategy serves as a useful benchmark in evaluating the performance of the other strategies in Table I, but is unlikely to appeal to most investors owing to its volatility and lack of diversification across asset classes. The second all-equity strategy splits its allocation equally across domestic and international stocks (Stocks/I). Although this strategy eschews exposure to fixed income asset classes, it has broad ex ante empirical support from prior studies on the benefits of international diversification [see, e.g., Bekaert, Hodrick, and Zhang (2009) and Christoffersen, Errunza, Jacobs, and Langlois (2012)]. In the Internet Appendix, we find that the Stocks/I strategy has similar performance to reasonable alternative specifications of fixed weights across domestic and international stocks.

3 Data

In this section, we describe the underlying data on asset class returns used in our simulation analyses. We take the perspective of a US couple saving for retirement. Given the paucity of

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[8] As of the second quarter of 2023, US stocks have a 42.5% weight in the global equity markets. See `https://www.sifma.org/wp-content/uploads/2023/04/SIFMA-Research-Quarterly-Equities-2Q23.pdf`.

statistical evidence on long-horizon asset class returns in the US data, we model forward-looking returns by examining the history of asset class returns from a broad cross section of developed economies. To this end, we use the panel of asset class returns in developed countries compiled by Anarkulova, Cederburg, and O'Doherty (2023). These data include monthly real returns for domestic stocks, international stocks, government bonds, and government bills for 38 developed countries. The data cover the period from 1890 to 2019, but the sample periods for individual countries vary based on data availability and the timing of economic development (i.e., a given country is included in the sample only for the period after it achieves developed status).

The starting point for constructing the Anarkulova, Cederburg, and O'Doherty (2023) dataset is the GFDatabase from Global Financial Data. For each sample country, the GFDatabase contains times series of total return indexes, price indexes, dividend yields, and total market capitalization for stocks; yields for ten-year government bonds and short-term bills; consumer price indexes; and exchange rates. Anarkulova, Cederburg, and O'Doherty (2022, 2023) provide detailed descriptions of their methods for selecting appropriate data series for each country, filling gaps in the GFDatabase using alternative sources, cleaning the data, calculating asset class returns, and adjusting these calculations for several periods surrounding major market disruptions (e.g., the closure of the New York Stock Exchange in 1914 at the onset of World War I and the Greek government bond default in 2012).

The Anarkulova, Cederburg, and O'Doherty (2023) data are a balanced panel in the sense that each country-month of data has non-missing returns for domestic stocks, international stocks, bonds, and bills. The nominal returns for domestic stocks, bonds, and bills for a given country are measured in the local currency; these nominal returns are then converted to real returns using the local inflation rate. The nominal international stock returns for a given country are market-capitalization-weighted averages of the nominal returns for all non-domestic stock markets, with appropriate adjustments for changes in exchange rates. Analogous to the calculations for the other asset classes, the nominal international stock returns are converted to real returns based on local inflation. As such, all asset class returns for a given country-month reflect the real investment outcomes of local investors in that month.

Anarkulova, Cederburg, and O'Doherty (2022, 2023) demonstrate that their broad sample of asset class returns allows for a more comprehensive characterization of potential investment outcomes relative to samples based on individual countries (e.g., the US or the UK). Although single-country samples are commonly used to calibrate inputs for investment simulations, such samples contain very few independent observations of long-horizon investment outcomes. Moreover, these samples are likely to suffer from both survivor bias [see, e.g., Brown, Goetzmann, and Ross (1995)] and easy data bias [see, e.g., Dimson, Marsh, and Staunton (2002)]. Fama and French (2002) and Avdis and Wachter (2017), for example, present direct evidence that the historical performance of US stocks over the postwar period likely exceeded ex ante expectations.[9]

In Table II, we list each individual sample country and the corresponding data coverage. Five countries — Denmark, France, Germany, the UK, and the US — are included in the sample over the full 1890 to 2019 period. The sample periods for the other countries are shorter owing to data availability and development classification status. Anarkulova, Cederburg, and O'Doherty (2023) report that their data cover 91% of the potential country-months in the developed country sample. Table II also presents the geometric average real return and the standard deviation of real return for each combination of country and asset class. For the pooled sample of all 29,919 country-month observations, the average returns for domestic stocks, international stocks, bonds, and bills are 0.37%, 0.43%, 0.10%, and 0.00%, respectively (untabulated). Based on comparisons with the pooled sample, the average real returns in the US sample are higher for domestic stocks, bonds, and bills and lower for international stocks. But the US is not an extreme outlier relative to other countries for any of the four asset classes.

4 Methods

In this section, we outline the structure and implementation of our bootstrap simulation methods for assessing household retirement savings outcomes under different asset allocation strategies. Section 4.1 describes the lifecycle design, including the separation of the lifecycle into working and retirement periods and the specification of mortality risk. Section 4.2 presents the stochastic process for employment status and labor income during the working period, and Section 4.3 outlines the calculation of Social Security benefits received during the retirement period. Section 4.4 defines and parameterizes household utility over retirement consumption and bequest. Section 4.5 provides a detailed description of the Monte Carlo simulation procedure.

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[9] The dataset construction methods in Anarkulova, Cederburg, and O'Doherty (2022, 2023) are intentionally designed to mitigate survivor bias and easy data bias. The sample inclusion dates for individual countries are based on ex ante measures of economic activity (e.g., the proportion of a country's labor force employed in the manufacturing and services sectors and the country's membership in global policy organizations like the Organisation for Economic Co-operation and Development), and the authors take significant steps to construct continuous monthly data series for each country. We refer readers to Anarkulova, Cederburg, and O'Doherty (2022, 2023) for detailed descriptions of the development classification approach, dataset construction, return measurement, special data issues, and dataset validation.

4.1 Lifecycle design

Households in our model are composed of a female and a male of equal age. Each member is assumed to be eligible to work and save during the 40-year period starting from age 25. An individual may, however, experience nonemployment during their potential working years, such that not all investors work the full 40 years. As described in Section 4.2, we use the earnings model of Guvenen, Karahan, Ozkan, and Song (2021) to simulate lifecycle earnings, and their model captures an empirical tendency for many individuals to experience long bouts of nonemployment. We assume that individuals save 10% of their income for retirement, so no contributions occur during nonemployment periods. The assumed 10% contribution rate is close to the mean and median contribution rates for participants in Vanguard defined-contribution plans (including both employee and employer contributions) in 2022 of 11.3% and 10.6%, respectively [Vanguard (2023)].[10] We also assume that individuals making less than \$15,000 (in 2022 dollars) in a given year do not contribute to their retirement plan, consistent with evidence of low retirement saving rates among this group [see, e.g., Vanguard (2023)].

At age 65, each individual leaves the workforce (either ending employment or nonemployment) and begins to draw from retirement savings and Social Security. We assume that investors use the popular 4% rule for retirement withdrawals [Bengen (1994)]. That is, they withdraw 4% of their account balance at retirement in the first year and inflation-adjusted amounts calculated from this base withdrawal in subsequent years. In reality, retirees use a variety of withdrawal strategies. The 4% rule is ubiquitous in popular press and common retirement advice, so we use it as a simple heuristic for retirement withdrawals.[11] We note that the inclusion of Social Security income as a lower bound on retirement consumption and bequests as a source of utility from excess savings at death both work to reduce differences in utilities between the 4% rule and dynamic withdrawal strategies that may reduce the probabilities of very low or very high terminal retirement account balances. In the Internet Appendix, we demonstrate that our main conclusions regarding the relative performance of the asset allocation strategies are robust to alternative retirement withdrawal rules. We also note that the outcomes of households who choose to annuitize fully at retirement will be reflected by our wealth at retirement results.

We model the lifespans of all individuals using gender-specific mortality tables from the SSA.[12] The SSA reports conditional death probabilities at each age for females and males. Our simulations

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[10] Poterba, Rauh, Venti, and Wise (2005, 2009) assume a 9% contribution rate to household retirement accounts.

[11] In Choi's (2022) review of the most popular personal finance books, he finds that seven of the 12 books offering explicit retirement spending advice recommend the 4% rule.

[12] See `https://www.ssa.gov/oact/HistEst/PerLifeTables/2022/PerLifeTables2022.html`.

incorporate longevity risk, so the lifespan of each individual is randomly determined. Both the female and the male in each couple are alive at age 25, but one or both may die before retirement at age 65. We retain couples in which both members die before retirement because these couples have bequests that depend on their investment strategies. We exclude couples who never save before the deaths of both spouses because these couples are not informative about differences across investment strategies.

Table III summarizes the distribution of age at death in years conditional on survival to age 25 based on the SSA data and our simulation procedure detailed below. The table reports the mean, standard deviation, and distributional percentiles for age at death for the household, the female, and the male. The statistics for the household correspond to the age of the last survivor from the couple at death. The mean age of the last survivor at death is 87.6 years, and the median age is 88.9 years. There is, however, considerable uncertainty over longevity outcomes. The 5th percentile of age at death for the couple is 70.8 years, and the 95th percentile is 100.0 years. This uncertainty is an important feature to consider in assessing the ability of the alternative investment strategies to fund consumption through retirement. The last column of Table III reports the likelihood that a given investor type dies before reaching retirement age. There is a 19.5% (11.8%) chance that the male (female) dies before age 65, and there is a 2.3% chance that neither member of the couple survives into the retirement period.

Under the assumption that all individuals save 10% of their income during their working years, the (unmodeled) consumption of all individuals before retirement is independent of their retirement investment strategy. As such, we do not study consumption during the working years and do not include it in the utility calculations. Our exclusion of pre-retirement consumption extends to potential survivor benefits from Social Security that are taken before retirement at 65, because these benefits do not depend on the chosen retirement investment strategy.

4.2 Lifecycle income

We model lifetime earnings using the model of Guvenen, Karahan, Ozkan, and Song (2021). Their flexible framework allows for investor heterogeneity, permanent and transitory income shocks, and employment and nonemployment states. They estimate the model to fit a large number of cross-sectional moments and time-series properties of lifecycle earnings data on millions of US workers from the SSA.

Following Guvenen, Karahan, Ozkan, and Song (2021), the annual income level for investor i

at age $\tau + 24$ is given by

$$Y_\tau^i = (1 - \nu_\tau^i) e^{(g(\tau) + \alpha^i + \beta^i f(\tau) + z_\tau^i + \varepsilon_\tau^i)}, \tag{1}$$

where $g(\tau)$ is a quadratic polynomial that fits the well-known hump shape of lifecycle earnings, $f(\tau)$ is a linear function increasing in τ, α^i and β^i are investor-specific parameters that affect the expected level and slope of earnings, respectively, z_τ^i is a persistent earnings component following

$$z_\tau^i = \rho z_{\tau-1}^i + \eta_\tau^i, \tag{2}$$

and ε_τ^i is a transitory earnings shock. The persistent earnings component coefficient ρ is estimated to be 0.96 for annual earnings, which implies a half-life of about 17 years. The permanent and transitory shocks (η_τ^i and ε_τ^i, respectively) each follow a normal mixture distribution. Finally, $\nu_\tau^i = 0$ represents full-year employment, whereas $\nu_\tau^i = 1$ is full-year nonemployment. This nonemployment variable takes values as follows,

$$\nu_\tau^i = \begin{cases} 0 & \text{with prob. } 1 - p_\nu(\tau, z_\tau^i), \\ \min\{1, \exp(\lambda)\} & \text{with prob. } p_\nu(\tau, z_\tau^i), \end{cases} \tag{3}$$

where $\lambda > 0$ is a parameter governing the probability of partial-year nonemployment, $p_\nu^i(\tau, z_\tau^i) = \frac{e^{\xi_\tau^i}}{1+e^{\xi_\tau^i}}$ is the nonemployment probability, and $\xi_\tau^i = a + bf(\tau) + cz_\tau^i + dz_\tau^i f(\tau)$ with $b < 0$, $c < 0$, and $d < 0$. As such, the probability of nonemployment is negatively influenced by the level of the persistent earnings component, which produces persistence in the nonemployment state.

The heterogeneity in earnings processes across investors is captured by two income parameters, α^i and β^i, and the initial state of the permanent income component, z_0^i. High (low) values for α^i and β^i designate investor types with high (low) levels and growth rates, respectively, for expected lifetime earnings, whereas high (low) z_0^i captures a tendency for high (low) early-career earnings. In our base case analyses, we set all three parameters for both members of the couple equal to their median values in the Guvenen, Karahan, Ozkan, and Song (2021) calibration, i.e., $(\alpha^i, \beta^i, z_0^i) = (0, 0, 0)$.

In practice, different investor types may prefer different asset allocation strategies due to differences in lifetime earnings and savings profiles. Investors with high $(\alpha^i, \beta^i, z_0^i)$, for example, have high expected lifetime savings, whereas those with low $(\alpha^i, \beta^i, z_0^i)$ will likely be more reliant on Social Security. The timing of income over the lifecycle can also affect investor preferences for different strategies because of effective differences in asset accumulation period lengths. In the

Internet Appendix, we provide a comprehensive investigation of how preferences for the alternative asset allocation policies differ across investor types.

We simulate from the income model using the parameter estimates from the replication code of Guvenen, Karahan, Ozkan, and Song (2021) with the additional assumption that the income model applies equally to females and males. We scale the simulation output (which does not initially have a standard unit of measurement) to match the level of average log earnings in 2010 dollars [Figure C.36 in Guvenen, Karahan, Ozkan, and Song (2021)] and then convert to 2022 dollars by adjusting for the change in the consumer price index (CPI).

4.3 Social Security benefits

Our simulations incorporate Social Security benefits and the additional social safety net from Supplemental Security Income (SSI). Social Security benefits are calculated based on taxes paid on earnings during working years. The Social Security system is progressive, in the sense that individuals with lower lifetime earnings receive larger benefits as a proportion of their taxes paid. We use the formulas effective in 2022 to calculate Social Security benefits based on each worker's earnings. We incorporate spousal and survivor benefits. We also apply the formulas for early retirement penalties and late retirement benefits. In our base case of retirement at age 65, the household is subject to a 13.3% penalty on personal retirement benefits, a 16.7% penalty on spousal benefits, and an 8.1% penalty on survivor benefits. In the Internet Appendix, we provide full details of the Social Security benefit calculations, including the calculation of average indexed monthly earnings (AIME), the bend points in the benefit formula, the scenarios for spousal and survivor benefits, and the effects of retirement age on benefits. Finally, SSI is available to retirees with little other income. The maximum monthly benefit in 2022 is \$1,261 for couples and \$841 for singles. We account for payments from this program to reflect the social safety net and to avoid numerical problems with utility calculations when retirement consumption is very low.

4.4 Household utility

Household utility is determined by monthly retirement consumption and a bequest. Following Duarte, Fonseca, Goodman, and Parker (2022), we scale household consumption by the square root of household size in the utility calculations to reflect differences in consumption needs for couples versus singles. That is, the consumption of a couple i in month t is divided by $\sqrt{H_t^i} = \sqrt{2}$ before computing utility, whereas consumption directly enters the utility function for single investors because $\sqrt{H_t^i} = 1$. We also follow Duarte, Fonseca, Goodman, and Parker (2022) by setting the subjective discount factor to one, which equally weights utility in each month of retirement to reflect the flow of utility during the retirement period. The total utility from monthly consumption during retirement and the bequest for couple i is

$$U(C^i, B^i) = \sum_{t=481}^{T_{max}^i} \frac{\left(C_t^i/\sqrt{H_t^i}\right)^{1-\gamma}}{1-\gamma} + \theta \frac{(B^i + k)^{1-\gamma}}{1-\gamma}, \tag{4}$$

where C_t^i is the consumption of household i in month t, B^i is the bequest of household i, θ and k are bequest utility parameters, and γ is the coefficient of relative risk aversion. Our bequest utility specification follows De Nardi, French, and Jones (2010). We use their estimate for risk aversion of $\gamma = 3.84$, and we assume that this risk aversion coefficient applies to both consumption and bequest. De Nardi, French, and Jones (2010) estimate a bequest intensity of $\theta = 2{,}360$ when studying bequest utility alongside utility from annual consumption, and we multiply this parameter estimate by 12^{γ} to reflect the mechanical difference in scaling between monthly and annual consumption levels.[13] Finally, we inflation-adjust their bequest curvature parameter k, which determines the extent to which bequests are viewed as luxury goods, and use $k = \$490{,}000$ in 2022 USD.

4.5 Simulation procedure

We simulate lifecycle outcomes for couples using a Monte Carlo simulation approach. We consider eight investment strategies that are adopted by otherwise identical couples in each draw (i.e., the couples in each draw have the same longevity, income, and savings and realize the same asset class returns). As such, our simulation design focuses on drawing inferences about the differences in outcomes based on the chosen investing strategy. Our simulation design includes the following steps in each draw.

1. We determine the lifespans of the male, the female, and the couple (i.e., the longer of the male and female lifespans). We generate random longevity using the conditional mortality probabilities for males and females reported by the SSA, and we assume that the probability of death is equal across the 12 months at a given age. We denote the realized lifespans of the female and the male as T_f^i and T_m^i, respectively, and the couple's lifespan in months (starting from age 25) as $T_{max}^i = \max(T_f^i, T_m^i)$.

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[13] Taking C_a as an arbitrary annual consumption level, the sum of utility from 12 months of consuming $C_m = C_a/12$ is $\sum_{t=1}^{12} \frac{C_m^{1-\gamma}}{1-\gamma} = 12 \frac{(C_a/12)^{1-\gamma}}{1-\gamma} = 12^{\gamma} \frac{(C_a)^{1-\gamma}}{1-\gamma}$.

2. We adopt the stationary block bootstrap approach of Anarkulova, Cederburg, and O'Doherty (2023) to draw a full time series of monthly real returns for the four asset classes. We draw blocks of consecutive monthly returns from the same country to capture time-series dependencies in asset returns. Block lengths are drawn from a geometric distribution with an average block length of 120 months, so the blocks reflect long-term time-series properties of returns. A set of all four asset class returns are drawn from each selected country-month to preserve cross-sectional dependencies across assets, and we denote a monthly real return vector as

   $$R_t = [R_t^{Domestic\ stocks} \qquad R_t^{International\ stocks} \qquad R_t^{Bonds} \qquad R_t^{Bills}]. \tag{5}$$

   We repeatedly draw blocks of returns from random countries and periods until we produce a time series of asset class returns that spans the viable investment period for the couple. This period extends from month $t = 2$ (i.e., the second month of age 25 and the first month in which the couple may have a positive beginning-of-month account balance) to month $t = T^i_{max}$. The final bootstrap draw of asset class returns in iteration m is $R = \{R_2, R_3, \ldots, R_{T^i_{max}}\}$. We refer readers to Anarkulova, Cederburg, and O'Doherty (2023) for full bootstrap details and robustness to average block length.

3. Given the chosen investment strategy for couple i, we compute a monthly time series of portfolio returns over the couple's lifetime. Denote the investment weights for the chosen strategy in month t as w^i_t. The portfolio return in month t is $R^i_t = w^i_t R'_t$.

4. The couple begins with no wealth in savings, $W^i_0 = 0$. We draw time series of annual earnings for each spouse using Guvenen, Karahan, Ozkan, and Song's (2021) model described in Section 4.2. Each investor saves a constant proportion (10% in the base case) of their monthly earnings, so long as their annual earnings for that year exceed $15,000. Denoting the total monthly savings of couple i during month $t+1$ as S^i_{t+1}, end-of-month wealth (W^i_{t+1}) evolves during the working years as

   $$W^i_{t+1} = W^i_t(1 + R^i_{t+1}) + S^i_{t+1}. \tag{6}$$

   If both members of a couple die before saving, we omit the household from our analysis and get a new draw.

5. At retirement, the couple stops working and saving. The 4% rule for retirement withdrawals

specifies that the couple will withdraw and consume 4% of the initial account balance in the first year of retirement and inflation-adjusted versions of this amount in subsequent years. Our simulation is in real terms, so our couples withdraw the same real amount each month in retirement until death or depletion of wealth. Given our assumption of a working lifespan from ages 25 to 65, beginning-of-retirement wealth is denoted as W_{480}^i and the monthly real withdrawal amount in retirement is

$$D_{t+1}^i = \min\left(\frac{1}{12}(0.04 \times W_{480}^i), W_t^i\right). \tag{7}$$

The situation in which $D_{t+1}^i = W_t^i$ occurs when beginning-of-month wealth is either zero or positive but insufficient to cover the usual withdrawal. Wealth evolves during retirement as

$$W_{t+1}^i = (W_t^i - D_{t+1}^i)(1 + R_{t+1}^i). \tag{8}$$

If the household's wealth is depleted at any time during retirement, it remains at zero until death. The household also receives monthly Social Security benefits, denoted as SS_{t+1}^i. The couple is supported by SSI if their income falls below the threshold denoted SSI_{t+1}^i (SSI_{t+1}^i = \$1,261 for couples and SSI_{t+1}^i = \$841 for singles). Total retirement income is given by

$$C_{t+1}^i = \max(D_{t+1}^i + SS_{t+1}^i, SSI_{t+1}^i). \tag{9}$$

Finally, the couple's bequest is all remaining wealth at the death of the last surviving spouse,

$$B^i = W_{T_{max}^i}^i. \tag{10}$$

We calculate utility over consumption and bequest, $U(C^i, B^i)$, following equation (4).

We repeat this process 1,000,000 times for each of the candidate investment strategies. We compile distributional statistics for wealth at retirement, the portfolio drawdown during the household's working period, the income replacement rate during retirement, the portfolio drawdown during the household's retirement period, and wealth at death (i.e., the bequest).[14] We also compute the time series of monthly consumption during retirement and household utility for each draw. Given

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[14] Maximum portfolio drawdowns are calculated as the largest real negative cumulative return relative to the previous peak. The working-period drawdown occurs entirely within the working years. The retirement-period drawdown begins with a peak that could occur either during the working years or the retirement years. That is, falling asset prices in the late working years can contribute to our measured retirement drawdown.

our assumptions, consumption prior to retirement is unaffected by the couple's choice for their investment strategy, so pre-retirement consumption is irrelevant for inferences about the strategies. The mean utility across draws is our Monte Carlo estimate of expected utility for a given investment strategy.

We make utility comparisons across strategies by running simulations as described above but with alternative savings rates. Given the retirement utility from a current investment strategy with the 10% base savings rate during working years, we find the savings rate associated with an alternative investment strategy that provides the same expected retirement utility. An alternative savings rate of 7%, for example, would indicate that a couple could reduce their savings rate from 10% to 7% without sacrificing wellbeing in retirement by switching to the alternative strategy, whereas an alternative savings rate of 15% would indicate that the couple would need to boost savings substantially under the alternative plan to maintain their expected utility in retirement.

5 Results

In this section, we examine retirement outcomes for couples who each use one of the investment strategies introduced in Section 2. Section 5.1 presents our main results on strategy performance using the block bootstrap simulation analysis described in Section 4. Section 5.2 considers asset class return properties in conjunction with strategy performance. Section 5.3 discusses investor types. Section 5.4 studies the conditions under which diversifying across stocks and bonds using an age-based strategy would appear beneficial.

5.1 Lifecycle investment strategy performance

We examine simulation results for couples who adopt a particular investment strategy. For each strategy, we study (i) the distribution of wealth at retirement, (ii) the distribution of the maximum drawdown during working years, (iii) the distribution of the income replacement rate to describe the consumption stream in retirement, (iv) the distribution of the maximum drawdown during retirement years, (v) the probability of exhausting financial wealth prior to death, and (vi) the distribution of wealth at death. We also calculate the expected utility generated from retirement consumption and bequest to study the economic magnitude of performance differences across strategies. Recall that our simulation design allows for a direct comparison across eight investment strategies used by otherwise identical couples, in that the couples in each draw have the same longevity, income and saving, and asset class return realizations. As such, any differences in retirement outcomes are directly attributable to the investment strategies.

5.1.1 Pre-retirement period

Table IV summarizes the distribution of wealth built up through the savings period by each investment strategy across 1,000,000 bootstrap simulations. The table reports wealth at retirement in millions of 2022 dollars. For each strategy, the table shows the mean, standard deviation, and percentiles of the wealth distribution at the beginning of the retirement period. The location and scale of the wealth distribution depend on our assumed 10% savings rate during the working years. For context in interpreting the wealth levels, couples save \$0.24 million on average. As reported in Table III, about 2.3% of households have both members die prior to retirement age. For these couples, bequests occur prior to retirement and wealth at retirement is \$0.

Panel A of Table IV characterizes wealth distributions for couples adopting a QDIA strategy. The TDF generates average retirement wealth of \$0.81 million. Given our assumed 4% retirement withdrawal rule, this average balance would support an annual real withdrawal for the couple of about \$32,400. This average does, however, mask substantial underlying variation in potential outcomes caused by variation in household income and asset class return realizations. The 90% interval for the TDF is \$0.10 million to \$2.10 million. These two retirement wealth levels imply real withdrawals of about \$3,900 and \$84,100 per year, such that uncertainty about income and returns during the working years drives wide variation in retirement outcomes.

The other QDIAs in Panel A generate distributions of retirement wealth that are generally similar to that of the TDF. These four strategies differ along two dimensions: (i) maintaining constant portfolio weights (Balanced and Balanced/I) or specifying age-based portfolio weights (Age and Age/I) and (ii) investing domestically (Balanced and Age) or diversifying internationally (Balanced/I and Age/I). The age-based strategies tend to produce more retirement wealth than the constant-weight strategies owing to higher equity allocations during the early working years, and the domestic strategies have more uncertain wealth outcomes compared with the internationally diversified strategies.

Panel B of Table IV reports distributional statistics for the Bills strategy, which mimics a money market fund. Investing in bills provides next to no real wealth creation, as the average household savings of \$0.24 million grows to an average of just \$0.28 million at retirement. Every QDIA dominates Bills throughout the entire distribution of retirement wealth. These results demonstrate that money market and stable value funds are poor retirement saving tools when used in isolation and provide support for the changes to default DC plan options brought about by the PPA.

Panel C of Table IV shows results for strategies that invest solely in equity, either without or with international diversification. Investing solely in domestic stocks produces an average wealth balance of \$1.05 million, which exceeds expected wealth from the QDIA strategies. The Stocks strategy does, however, carry a higher risk of a poor outcome compared with the TDF, Balanced/I, and Age/I strategies. For example, the 10th percentile outcome for Stocks is \$0.14 million versus \$0.17 million for the TDF. The simulation results echo common intuition that an undiversified investment in domestic stocks carries higher downside risk compared with strategies that are diversified across asset classes.

Panel C also summarizes the wealth distribution for a diversified equity investment in domestic and international stocks. Adopting this Stocks/I strategy generates \$1.07 million of retirement wealth on average, comparable to the strong average performance of the Stocks strategy. This average wealth level supports an annual retirement withdrawal of about \$42,900, which is meaningfully higher than the average TDF withdrawal of \$32,400. Interestingly, the Stocks/I strategy provides households with impressive upside without sacrificing on the downside, and the left-tail wealth levels for Stocks/I exceed those for the TDF. The Stocks/I strategy aggressively pursues the superior expected performance of equity relative to fixed income, and international diversification provides important benefits for limiting downside risk during the saving years.

Table V summarizes the distribution of the maximum drawdown during working years for each strategy. The reported drawdowns are the largest working-period peak-to-trough declines in asset values for a given strategy, and they are expressed in decimal form. The simulation results in Panel A show that large real drawdowns often occur with the QDIAs. The mean maximal drawdowns during the savings period from age 25 to 65 range from 46% (Balanced/I) to 60% (Age). Bills have a lower average drawdown of 39%, as reported in Panel B. In real terms, bills still have the potential for large drawdowns if the economy has an extended inflationary period, and the largest drawdowns for the Bills strategy are larger than those for the QDIA strategies.

The all-equity strategies in Panel C of Table V tend to produce relatively large intermediate drawdowns. The average drawdown of 68% for stocks is the highest across the strategies we consider. Stocks/I has a mean drawdown of 57%, which is somewhat higher than the drawdowns of the QDIAs with the exception of the Age strategy. It is important to note, however, that Stocks/I dominates the QDIAs in retirement wealth outcomes (Table IV) despite these larger intermediate drawdowns (Table V). Couples who stay the course with Stocks/I achieve better results.

5.1.2 Retirement period

Table VI shows distributions of income replacement rates during retirement for each strategy. The reported replacement rates are calculated as the mean of monthly household retirement consumption divided by the mean of monthly household income during the working ages of 25 to 65.[15] Due to simulation design, household income is identical across strategies as are household Social Security benefits. The variation in income replacement rates across strategies is therefore driven by differences in withdrawals from retirement savings. Using the 4% rule, the initial withdrawal amount is proportional to wealth at retirement, such that those strategies with good performance in Table IV tend to produce higher replacement rates. Strategies that avoid depleting wealth also tend to provide higher mean consumption because households can continue to make withdrawals late in their lives. Income replacement rates thus balance the need to grow wealth during saving years and preserve wealth during retirement. In addition to the mean, standard deviation, and percentiles of the distribution, Table VI reports the probability that the income replacement rate is less than one (i.e., that the couple must cut consumption in retirement years relative to their working years) in the last column.

Panel A of Table VI reports that the QDIA strategies (along with Social Security benefits) allow couples to achieve full income replacement, on average. The mean replacement rate for the TDF is 1.06, though 58.9% of couples have a replacement rate below one. The other QDIAs are generally similar to the TDF. The poor long-term appreciation of the Bills strategy shows through in Panel B, as the average replacement rate is just 0.71 and 93.0% of couples must cut consumption in retirement.

The superior wealth accumulation of the Stocks/I strategy gives it a natural advantage in producing high income replacement rates. Wealthy people can spend more. The strategy does, however, eschew the typical wealth preservation approach of diversifying into fixed income as the household ages. If households quickly run out of savings due to poor investment performance in retirement, mean retirement consumption and the replacement rate will suffer. The results in Table VI demonstrate, however, that Stocks/I facilitates better retirement consumption relative to the other asset allocation approaches. Stocks/I produces a mean replacement rate of 1.24 and more than half (54.8%) of couples achieve full replacement or better. Perhaps surprisingly, the left-tail outcomes for Stocks/I also exceed those for the QDIA strategies that diversify into fixed income in an attempt to preserve wealth in retirement.

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[15] The replacement rate is equal to 0.00 for couples who are deceased prior to retirement.

Table VII reports distributional statistics for retirement-period drawdowns. Given regulators' focus on short-term losses, it is important to compare the intermediate drawdowns for the QDIAs with those of the non-QDIA Stocks/I strategy. The three QDIAs that diversify internationally have mean drawdowns of 38% (TDF), 40% (Balanced/I), and 38% (Age/I), which are all low compared with the 50% average drawdown for Stocks/I. The 95th percentile for Stocks/I of 77% is superior to those for the TDF (86%), Balanced/I (79%), and Age/I (81%) strategies, but the QDIAs typically avoid drawdowns as large as those for Stocks/I.

5.1.3 Wealth preservation and bequest

Table VIII displays distributional statistics for real wealth at the death of the last survivor in the household. The bequest from wealth at death occurs after retirement for most couples, but the households in which neither member survives until retirement have earlier bequests. A couples's bequest is $0 if they experience financial ruin prior to death, and Table VIII reports this probability for each strategy in the last column. The table reports wealth in millions of 2022 dollars.

Panel A of Table VIII indicates that the QDIA investors we study are able to leave substantial bequests on average. The mean wealth at death is $0.86 million for the TDF, and average bequests for the other QDIAs range from $1.10 million (Age/I) to $1.30 million (Balanced). The distributions of wealth at death are, however, noticeably more right-skewed compared with the distributions of wealth at retirement in Table IV, reflecting the potential for compounding over the long lifespan of a couple. The median bequests range from $0.35 million for the TDF to $0.52 million for Balanced/I, and the 99th percentiles reach as high as $12.53 million (Balanced). Couples adopting QDIAs also have non-trivial ruin probabilities. The probability of exhausting financial wealth prior to death with the TDF is 16.9%, which is likely a greater risk than most households would like to face. The Balanced/I strategy has the lowest ruin probability among the QDIAs at 10.9%. Couples who experience financial ruin must rely solely on Social Security and SSI benefits after exhausting their savings.

The results for Bills in Panel B of Table VIII show that these "safe" fixed income products represent a risky retirement strategy. The median wealth at death is just $0.03 million, and 35.7% of couples investing in bills run out of savings.

The equity strategies in Panel C of Table VIII provide couples with the potential to generate substantial bequests. The mean bequests are $2.81 million for Stocks and $2.97 million for Stocks/I, though these means are heavily influenced by a long right tail of outcomes (e.g., the 99th percentiles are $34.95 million and $31.46 million for Stocks and Stocks/I, respectively). Stocks/I, in particular, generates a bequest distribution that is quite favorable relative to all alternative strategies in Panels A to C.

The Stocks and Stocks/I strategies produce starkly different outcomes for income stability. The Stocks strategy has a 17.4% ruin probability. Each of the QDIAs gives households a lower chance of exhausting their savings compared with investing solely in domestic stocks. The ruin probability for Stocks/I, in contrast, is only 8.2%. Equity offers strong potential for additional investment gains during retirement, and international diversification is crucial for preserving wealth. Stocks/I outperforms all QDIAs, and the 8.2% ruin probability is less than half of the 16.9% probability for the TDF that is designed for wealth preservation in retirement.

5.1.4 Summary of strategy performance

Figure 3 provides a visual summary of the eight investment strategies along six dimensions. Panel A shows box-and-whiskers plots of the distribution of retirement wealth for each strategy. The middle line is the median, the box designates the interquartile range, and the whiskers extend to the 10th and 90th percentiles. Panels B, C, D, and F contain analogous plots for working-period drawdown, replacement rate, retirement-period drawdown, and bequest, respectively, and Panel E marks ruin probabilities. The figure makes clear the consistent performance of Stocks/I across all outcomes of wealth accumulation, spending, and bequest. Relative to the other strategies, Stocks/I is an outlier in achieving desirable retirement outcomes. These favorable retirement outcomes occur despite the tendency for Stocks/I to have larger intermediate drawdowns (Panels B and D) compared with most of the QDIAs.

5.1.5 Economic value

Table IX provides an analysis of the economic differences across investment plans. The table specifically reports equivalent savings rates that would provide the household with the same expected utility in retirement as a 10.0% savings rate in the base strategy. Each row of the table reports results for a different base allocation strategy, and each column reports a different alternative strategy.

The equivalent savings rates in Table IX reveal large economic differences across strategies. Taking a 10.0% savings rate in the TDF as the base, the couple could reduce savings modestly without sacrificing retirement welfare by switching to the Age/I strategy (9.4% equivalent savings rate). More strikingly, this household could achieve the same utility by saving just 7.2% in Stocks/I.

The economic magnitudes of utility differences are most obvious for the couples using Stocks/I as their base strategy. To achieve the same expected utility in retirement as a 10.0% savings rate in Stocks/I, the couple would be required to save anywhere from 13.2% (Age/I) to 46.9% (Bills) of its annual income during working years. The percentage increases in savings across the QDIAs relative to the Stocks/I base range from 32% (Age/I) to 69% (Balanced). Given the magnitude of annual retirement savings contributions ($586 billion in 2020), these savings rate differences imply massive societal welfare benefits from adopting Stocks/I as the new standard in retirement savings.[16]

5.2 Asset classes and strategy performance

Bonds are typically viewed as important tools for capital preservation and diversification, but the Stocks/I strategy deliberately avoids them and dominates popular bond-based strategies. In the Internet Appendix, we go one step further and demonstrate that Stocks/I even beats a strategy that replaces just 5% of the equity exposure with bonds over the couple's lifetime. For investors who adopt constant-weight strategies and have no ability to short an asset class, the optimal weight in bonds is 0%. Strategies that hold 5% or 10% in bonds only during the retirement period produce negligible gains relative to Stocks/I, and Stocks/I dominates any strategy with a retirement bond weight of 15% or higher. Our general conclusion is that bonds add virtually no value for the lifecycle investors we consider.

Inflation and investment horizon are critical for investors who consider bonds and are concerned with real performance. Anarkulova, Cederburg, and O'Doherty (2023) show that the negative correlation between real bond returns and inflation grows from -0.33 at a one-month horizon to -0.74 at a 30-year horizon. Domestic stocks and, in particular, international stocks provide better inflation hedges with long-horizon correlations of -0.30 and -0.03 with inflation, respectively. In the Internet Appendix, we examine strategy performance conditional on ex post inflation realizations. Whereas Stocks/I dominates the TDF in generating wealth at retirement and bequest regardless of the inflation outcome, the TDF produces slightly lower ruin probabilities than Stocks/I for very low inflation realizations during retirement. In the bottom ex post retirement inflation quintile, the TDF has a ruin probability of 1.0% versus 1.4% for Stocks/I. In the top quintile, however, the TDF has a 56.5% ruin probably compared with 18.5% for Stocks/I. The bonds in QDIAs carry large inflation exposure over long horizons.

The diversification benefits of bonds also depend on horizon. Anarkulova, Cederburg, and

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[16] The magnitude of the estimated utility gains depends on household risk aversion, but our conclusion that Stocks/I is the preferred strategy holds for all γ values between zero and ten.

O'Doherty (2023) estimate a correlation of 0.18 between one-month real returns on domestic stocks and bonds. This correlation increases to 0.46 at a 30-year horizon, however, such that bonds offer less diversification benefit for long-horizon investors while giving low average returns. International stocks, in contrast, offer high average returns and better diversification with a 30-year correlation between real returns on domestic stocks and international stocks of 0.35.

The high average returns of domestic stocks and international stocks in the Stocks/I strategy also protect investors from longevity risk. In the Internet Appendix, we show that Stocks/I dominates the TDF in each quintile of realized household longevity, but the differences are most pronounced for long-lived couples. For example, the ruin probability of the TDF for the shortest-lived quintile is 1.7% versus 0.6% for Stocks/I. For those couples who live the longest, the ruin probabilities are 35.1% for the TDF and 16.6% for Stocks/I. Uncertain mortality implies that all households are, to some degree, long-horizon investors.

Finally, retirement savers and retirees may be rightfully concerned about the possibility that the stock market will perform poorly during their lifetime. A poor stock market outcome would seem to sound the death knell for Stocks/I, whereas the TDF and other QDIAs may offer protection by diversifying into fixed income. In the Internet Appendix, we condition on the ex post realization of the couple's real return on domestic stocks. Interestingly, Stocks/I dominates the TDF in each quintile of realized stock return. When domestic equity does poorly, bonds and bills also tend to do poorly. Fixed income does not offer an adequate safe haven against poor equity outcomes over the long run.

5.3 Alternative investors

Our base analysis studies US households with median parameter values in the lifetime earnings model of Guvenen, Karahan, Ozkan, and Song (2021). We now consider alternative US investor types and non-US investors.

5.3.1 US investor types

In the Internet Appendix, we study four household types who differ along two dimensions: low or high human capital $[(\alpha^i, \beta^i)]$ and low or high initial income $[z_0^i]$. These parameter combinations produce a variety of lifetime earnings profiles (i.e., saving more early versus later in the working years) and total lifetime earnings levels (i.e., earning very little versus earning a lot). Despite the differences in savings behavior across households, our conclusion that Stocks/I dominates the alternatives holds for each investor type. Relative to the QDIAs we consider, Stocks/I provides a one-size-fits-all approach to lifetime savings.

5.3.2 Non-US investors

Our treatment of return data, which takes the perspective of an investor domiciled in a developed country, implies that our broad conclusions are likely to generalize to non-US investors. Other countries differ from the US in important ways, however. We calibrate to American Social Security and longevity. Other countries adopt different retirement systems and normal retirement ages, and many developed countries enjoy greater longevity compared with the US.[17] Earlier retirements and longer lifespans increase the need for additional investment gains during retirement. We find that the dominance of Stocks/I is even more pronounced for the longest-lived couples, which suggests that investors in other developed countries will benefit from the all-equity approach.

An allocation strategy of 50% to US stocks and 50% to international stocks is roughly in line with global equity market weights, which should be appealing to American investors. For investors in other countries, an even allocation across domestic and international markets would represent a strong home bias. In the Internet Appendix, we demonstrate that reducing the domestic stock weight to 35% (and investing 65% internationally) produces small performance improvements relative to the Stocks/I strategy. This 35% domestic weight remains a large home bias for non-US investors, but we show that further reductions in domestic investments come at a cost of worse performance. As such, our results suggest that non-US investors should have a home bias in their equity portfolios.

5.4 Methodological choices in lifecycle strategy evaluation

Our lifecycle simulation methods detailed in Section 4 have two important differences compared with common approaches: (i) we adopt a block bootstrap with long blocks (120 months on average) to preserve time-series dependencies in returns and (ii) we use a comprehensive dataset of developed country returns spanning nearly 2,500 years rather than relying on the short US return history to make inferences about long-run outcomes. In this section, we investigate the sensitivity of our conclusions to these two design features. This analysis provides some sense of robustness, and it helps us reconcile our finding that Stocks/I dominates alternative strategies with the central tenets that retirement savers should diversify across stocks and bonds using age-based strategies.

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[17] According to the World Bank, for example, the current life expectancy in the US is 76.3 years versus 80.4 years in the European Union. See `https://data.worldbank.org/indicator/SP.DYN.LE00.IN`.

To compare with our base case of using the developed country sample and a block bootstrap (denoted Dev-Block), we consider three alternative simulation designs: (i) the developed sample with an IID bootstrap (Dev-IID), (ii) the US sample with a block bootstrap (US-Block), and (iii) the US sample with an IID bootstrap (US-IID). Figure 4 shows retirement outcomes and intermediate drawdowns for a representative QDIA strategy (Age) and the dominant non-QDIA strategy (Stocks/I).

Examining results in Figure 4 for the base Dev-Block approach and the alternative Dev-IID approach isolates the effects of maintaining time-series dependencies in returns. There is an understatement of uncertainty over wealth at retirement and mean replacement rate for the Age strategy under the assumption that returns are IID, but these outcomes are comparable overall. More noticeable differences exist for drawdowns and ruin probability. Drawdowns for both strategies appear much smaller under the IID assumption. The average drawdowns in retirement, for example, are 47% for Age and 50% for Stocks/I under base Dev-Block method versus estimates of 37% and 39%, respectively, with the Dev-IID approach. The base ruin probabilities of 16.8% (Age) and 8.2% (Stocks/I) are also high relative to the IID estimates of 12.9% (Age) and 6.8% (Stocks/I). Nonetheless, the Stocks/I strategy dominates the Age strategy using either the block bootstrap or the IID bootstrap with the developed country sample.

Comparing across the Dev-Block and US-Block approaches in Figure 4 isolates the effects of the sample. The US sample provides a noticeably more optimistic view of the Age strategy for wealth at retirement, income replacement, and wealth at death. The working-period and retirement-period drawdowns are substantially smaller for the Age strategy using the US sample. Strikingly, the ruin probabilities for both strategies are quite low using the US-Block approach rather than the Dev-Block approach. With the US sample, the ruin probabilities are just 6.0% for Age and 5.2% for Stocks/I. Despite the rosier picture of the Age QDIA painted by the US data, however, our conclusion that Stocks/I dominates Age is apparent using either the Dev-Block method or the US-Block method.

Figure 4 also shows results for the US-IID approach, which uses short-term return information from US data to make inferences about long-horizon retirement outcomes. Under this specification, the Age and Stocks/I strategies produce relatively similar distributions for wealth at retirement and mean replacement income. Stocks/I continues to outperform Age in bequest. In terms of both retirement drawdown and ruin probability, however, Age appears better than Stocks/I with the US-IID method. The average retirement drawdown is just 24% for Age versus 35% for Stocks/I, and Age has a lower ruin probability of 4.1% compared with Stocks/I at 4.8%. A couple who is more focused on maintaining a safe consumption stream in retirement rather than leaving an inheritance may prefer the QDIA Age strategy to the non-QDIA Stocks/I strategy if they use the US-IID method.

Table X presents a summary of the effects of methodological choices across all eight strategies. The table focuses, in particular, on ruin probabilities. Estimated probabilities of ruin are almost uniformly lower under IID bootstraps compared with block bootstraps, which illustrates the importance of maintaining time-series dependencies in returns while studying lifecycle investing. All US-based loss probabilities are lower than their developed country counterparts. As previously discussed, historical US data may provide overly optimistic predictions of future investment performance. If so, the large historical sample of developed country returns gives investors a more realistic view of the range of potential outcomes.

Table X shows that most of the QDIAs have lower ruin probabilities than Stocks/I using the US-IID method. This approach is similar in nature to the analyses in many academic and practitioner outlets (e.g., those that use monthly return moments from US data to calibrate models), which may explain the broad-based support for age-based, stock-bond investing. It is important to note, however, that this method ignores two realities. Returns are not IID, and the US sample is very short for making long-horizon inferences. Accepting *either* of these facts reinstates Stocks/I as the dominant strategy.

6 Conclusion

We challenge two central tenets of lifecycle investing — savers should diversify across stocks and bonds and the young should invest more heavily in stocks than the old. These principles underly mainstream investment advice and permeate regulations for DC pension plans. We find that a constant allocation of 50% to domestic stocks and 50% to international stocks throughout one's lifecycle dominates QDIAs in all retirement outcomes. Two important aspects of our method, namely the preservation of time-series dependencies in returns and the use of a comprehensive dataset of developed country returns, appear important in reaching this conclusion. The QDIAs seem favorable for retirees under the assumptions that returns are IID and that historical US returns are most informative about future performance. These two assumptions resemble those from many common approaches to lifecycle investing, but rejecting either leads back to the conclusion that the Stocks/I strategy dominates the QDIAs.

Despite the dominance of Stocks/I in achieving retirement outcomes, investors and regulators may be uncomfortable with the tendency for larger intermediate drawdowns using the all-equity strategy. Drawdowns inflict psychological pain, and some investors may abandon their investments rather than stay the course. We are sympathetic to the discomfort and real costs of these bouts of poor short-run performance. In our opinion, however, reducing these short-run losses by adopting a QDIA strategy comes at too high a price because investors must forego the enormous economic gains from adopting the Stocks/I strategy (estimated to be hundreds of billions of dollars per year for US investors alone). Our findings suggest that financial advice and pension regulations should be revised to consider all-equity strategies as viable and legal alternatives for retirement savers; we call for alternative approaches to mitigate the costs of short-term losses, such as financial education on staying the course, retirement account reporting standards that emphasize long-term performance, and regulations that assist retirement savers with maintaining a long-term focus.

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Table I: Asset allocation strategies

The table provides descriptions of the asset allocation strategies considered in the paper. The abbreviations are used to refer to the strategies in subsequent tables and figures.

Num	Abbreviation	Strategy description	Asset class weights
Panel A: Safe harbor strategies			
1	TDF	The asset class weights follow the glidepath of a target-date fund strategy, which specifies age-based allocations to domestic stocks, international stocks, bonds, and bills.	See Figure 1
2	Balanced	The strategy invests in domestic stocks and bonds with a constant allocation to each asset class.	Domestic stocks: 60% Bonds: 40%
3	Balanced/I	The strategy invests in stocks and bonds with a constant allocation to each asset class. The stock allocation is split evenly between domestic stocks and international stocks.	Domestic stocks: 30% International stocks: 30% Bonds: 40%
4	Age	The strategy invests in domestic stocks and bonds following the "120−Age" heuristic.	Domestic stocks: (120−Age)% Bonds: (Age−20)%
5	Age/I	The strategy invests in stocks and bonds following the "120−Age" heuristic. The stock allocation is split evenly between domestic stocks and international stocks.	Domestic stocks: (60−Age/2)% International stocks: (60−Age/2)% Bonds: (Age−20)%
Panel B: Capital preservation strategy			
6	Bills	The strategy invests solely in bills.	Bills: 100%
Panel C: Equity strategies			
7	Stocks	The strategy invests solely in domestic stocks.	Domestic stocks: 100%
8	Stocks/I	The strategy invests solely in stocks, and the investment is split evenly between domestic stocks and international stocks.	Domestic stocks: 50% International stocks: 50%

TABLE II: SAMPLE COVERAGE AND SUMMARY STATISTICS

For each developed country, the table reports the sample period start date, the sample period end date, and summary statistics (i.e., geometric mean return and standard deviation of return) for monthly real returns for domestic stocks, international stocks, bonds, and bills. The development classification and sample formation criteria are from Anarkulova, Cederburg, and O'Doherty (2023).

			Asset class returns							
			Domestic stocks		International stocks		Bonds		Bills	
Country	Sample start	Sample end	Mean	StDev	Mean	StDev	Mean	StDev	Mean	StDev
Denmark	1890:01	2019:12	0.33	3.54	0.38	3.90	0.23	1.85	0.18	0.72
France	1890:01	2019:12	0.30	5.40	0.42	6.67	−0.06	2.27	−0.16	1.77
Germany	1890:01	2019:12	0.26	8.35	0.56	10.26	−0.12	46.30	0.17	0.86
United Kingdom	1890:01	2019:12	0.38	4.28	0.45	4.09	0.16	1.93	0.07	0.87
United States	1890:01	2019:12	0.52	4.99	0.33	3.78	0.14	1.73	0.06	0.61
Canada	1891:01	2019:12	0.48	4.24	0.42	3.47	0.19	1.62	0.12	0.57
New Zealand	1896:01	2019:12	0.50	3.65	0.43	4.09	0.15	1.80	0.15	0.59
Belgium	1897:01	2019:12	0.22	5.01	0.38	4.54	0.04	1.76	−0.03	1.14
Australia	1901:01	2019:12	0.58	3.90	0.42	3.76	0.16	1.68	0.07	0.54
Sweden	1910:01	2019:12	0.47	4.82	0.44	4.14	0.17	1.81	0.09	0.97
Netherlands	1914:01	2019:12	0.40	5.09	0.41	4.37	0.16	1.66	0.02	0.78
Switzerland	1914:01	2019:12	0.39	4.31	0.38	4.46	0.16	1.38	0.03	0.62
Norway	1914:02	2019:12	0.39	5.06	0.44	4.21	0.15	1.70	0.02	0.86
Austria	1925:02	2019:12	0.27	5.18	0.57	12.43	0.16	2.67	−0.00	1.50
Czechoslovakia	1926:01	1945:05	−0.45	6.89	0.25	6.23	0.30	3.03	0.10	2.87
Chile period I	1927:01	1970:12	0.13	6.15	0.62	8.49	−0.92	3.38	−0.86	2.34
Japan	1930:01	2019:12	0.30	6.67	0.49	16.21	−0.18	3.47	−0.33	2.67
Italy	1931:01	2019:12	0.17	7.41	0.44	13.15	−0.12	2.54	−0.25	1.71
Portugal	1934:01	2019:12	0.13	7.92	0.45	4.03	0.05	2.80	−0.06	1.36
Ireland	1936:01	2019:12	0.46	4.67	0.47	4.03	0.20	2.38	0.03	0.59
Argentina	1947:02	1966:12	−0.18	8.53	0.64	15.34	−1.66	2.84	−1.56	2.73
Spain	1959:01	2019:12	0.34	5.48	0.39	4.22	0.20	2.17	0.02	0.69
Finland	1969:01	2019:12	0.78	6.31	0.41	4.31	0.32	2.21	0.06	0.46
Greece	1981:02	2019:12	0.45	10.36	0.54	4.71	0.36	5.55	0.16	1.27
Luxembourg	1982:01	2019:12	0.58	5.50	0.58	4.47	0.39	1.76	0.13	0.58
Singapore	1998:07	2019:12	0.53	5.94	0.27	3.99	0.22	1.99	−0.02	0.47

(continued on next page)

TABLE II *(continued)*

			Asset class returns							
			Domestic stocks		International stocks		Bonds		Bills	
Country	Sample start	Sample end	Mean	StDev	Mean	StDev	Mean	StDev	Mean	StDev
Hungary	1999:02	2019:12	0.46	6.44	0.26	4.08	0.40	3.31	0.18	0.40
Poland	1999:06	2019:12	0.32	5.98	0.23	3.66	0.44	2.48	0.22	0.41
Slovakia	2000:01	2019:12	0.37	5.33	−0.06	4.13	0.49	2.89	−0.04	0.58
Czech Republic	2000:05	2019:12	0.86	7.07	−0.00	4.18	0.25	2.16	−0.04	0.43
South Korea	2000:11	2019:12	0.70	6.15	0.27	3.73	0.37	1.90	0.09	0.34
Mexico	2001:08	2019:12	0.67	4.75	0.53	3.53	0.39	2.55	0.15	0.38
Iceland	2002:01	2019:12	−0.07	7.66	0.31	4.86	0.36	3.30	0.23	0.53
Chile period II	2010:01	2019:12	−0.03	4.06	0.78	3.54	0.14	1.37	0.03	0.36
Israel	2010:01	2019:12	−0.06	4.81	0.66	3.36	0.59	1.86	0.11	0.85
Slovenia	2010:01	2019:12	0.29	4.03	0.86	3.18	0.45	2.98	−0.02	0.76
Türkiye	2010:02	2019:12	0.05	6.44	1.13	5.04	0.00	4.88	0.06	0.94
Latvia	2016:01	2019:12	0.97	3.54	0.61	2.96	0.05	1.33	−0.21	0.47
Lithuania	2018:01	2019:12	0.18	2.61	0.61	3.52	0.16	1.31	−0.21	0.49

Table III: Distribution of age at death

The table summarizes the distribution of age at death in years conditional on survival to age 25 based on the actuarial life tables from the SSA. For each investor type (i.e., heterosexual couple, female, or male), the table reports the mean, standard deviation, and distribution percentiles of the age at death. The statistics for the couple correspond to the age of the last survivor at death. The last column in the table shows the likelihood of death prior to reaching retirement age.

	Moments		Percentiles									
Investor	Mean	StDev	1%	5%	10%	25%	50%	75%	90%	95%	99%	$\mathbb{E}[\mathbf{1}_{L_i<65}]$
Couple	87.6	9.1	59.4	70.8	76.1	83.0	88.9	93.8	97.7	100.0	104.4	0.023
Female	81.9	13.8	35.9	54.3	62.8	75.5	84.9	91.5	96.3	98.9	103.8	0.118
Male	77.1	15.3	30.6	46.0	55.8	68.9	80.6	88.3	93.5	96.2	101.0	0.195

TABLE IV: WEALTH AT RETIREMENT

The table summarizes the distribution of real wealth at retirement across 1,000,000 bootstrap simulations for households adopting various asset allocation strategies. Household income in the pre-retirement period is stochastic and follows the process estimated by Guvenen, Karahan, Ozkan, and Song (2021). The household's savings rate in the pre-retirement period is 10%. Household income in the post-retirement period is the sum of Social Security income and a constant real withdrawal of 4% of the household's investment account value at retirement (as long as the account has not been depleted). The household faces uncertainty over labor income, investment returns, and longevity. For each asset allocation strategy, the table reports the mean, standard deviation, and distribution percentiles of real wealth at retirement in millions of 2022 USD.

	Moments		Percentiles								
Strategy	Mean	StDev	1%	5%	10%	25%	50%	75%	90%	95%	99%
Panel A: Safe harbor strategies											
TDF	0.81	1.43	0.00	0.10	0.17	0.33	0.58	0.98	1.57	2.10	3.97
Balanced	0.76	1.69	0.00	0.07	0.14	0.27	0.51	0.91	1.50	2.05	3.96
Balanced/I	0.75	1.29	0.00	0.09	0.16	0.31	0.55	0.91	1.42	1.88	3.51
Age	0.82	1.80	0.00	0.07	0.14	0.29	0.55	0.98	1.64	2.27	4.52
Age/I	0.82	1.33	0.00	0.10	0.18	0.33	0.59	0.99	1.57	2.10	4.00
Panel B: Capital preservation strategy											
Bills	0.28	0.21	0.00	0.03	0.07	0.14	0.24	0.38	0.55	0.68	1.00
Panel C: Equity strategies											
Stocks	1.05	1.73	0.00	0.07	0.14	0.30	0.62	1.22	2.23	3.27	7.14
Stocks/I	1.07	1.41	0.00	0.12	0.21	0.40	0.73	1.29	2.16	3.00	6.11

Table V: Working-period drawdown

The table summarizes the distribution of the maximum portfolio drawdown during the pre-retirement period across 1,000,000 bootstrap simulations for households adopting various asset allocation strategies. Household income in the pre-retirement period is stochastic and follows the process estimated by Guvenen, Karahan, Ozkan, and Song (2021). The household's savings rate in the pre-retirement period is 10%. Household income in the post-retirement period is the sum of Social Security income and a constant real withdrawal of 4% of the household's investment account value at retirement (as long as the account has not been depleted). The household faces uncertainty over labor income, investment returns, and longevity. For each asset allocation strategy, the table reports the mean, standard deviation, and distribution percentiles of the maximum portfolio drawdown.

	Moments		Percentiles								
Strategy	Mean	StDev	1%	5%	10%	25%	50%	75%	90%	95%	99%
Panel A: Safe harbor strategies											
TDF	0.52	0.16	0.21	0.28	0.32	0.41	0.51	0.61	0.74	0.81	0.94
Balanced	0.54	0.19	0.21	0.28	0.32	0.40	0.50	0.66	0.82	0.91	0.99
Balanced/I	0.46	0.17	0.17	0.24	0.27	0.34	0.42	0.56	0.70	0.81	0.95
Age	0.60	0.18	0.26	0.33	0.38	0.47	0.58	0.71	0.87	0.92	0.99
Age/I	0.50	0.15	0.20	0.27	0.31	0.40	0.49	0.58	0.71	0.79	0.92
Panel B: Capital preservation strategy											
Bills	0.39	0.26	0.03	0.07	0.10	0.18	0.33	0.54	0.80	0.94	0.99
Panel C: Equity strategies											
Stocks	0.68	0.16	0.31	0.42	0.47	0.56	0.67	0.78	0.92	0.96	0.99
Stocks/I	0.57	0.13	0.25	0.33	0.39	0.49	0.57	0.65	0.75	0.78	0.92

Table VI: Income replacement rate

The table summarizes the distribution of the real income replacement rate across 1,000,000 bootstrap simulations for households adopting various asset allocation strategies. Household income in the pre-retirement period is stochastic and follows the process estimated by Guvenen, Karahan, Ozkan, and Song (2021). The household's savings rate in the pre-retirement period is 10%. Household income in the post-retirement period is the sum of Social Security income and a constant real withdrawal of 4% of the household's investment account value at retirement (as long as the account has not been depleted). The household faces uncertainty over labor income, investment returns, and longevity. For each asset allocation strategy, the table reports the mean, standard deviation, and distribution percentiles of the real income replacement rate. The last column in the table shows the proportion of simulations in which the real income replacement rate is less than one.

	Moments		Percentiles									
Strategy	Mean	StDev	1%	5%	10%	25%	50%	75%	90%	95%	99%	$\mathbb{E}[\mathbf{1}_{\pi<1}]$
Panel A: Safe harbor strategies												
TDF	1.06	1.38	0.00	0.54	0.62	0.75	0.93	1.18	1.56	1.93	3.32	0.589
Balanced	1.02	1.49	0.00	0.51	0.58	0.71	0.89	1.14	1.51	1.87	3.24	0.634
Balanced/I	1.02	1.33	0.00	0.54	0.62	0.75	0.91	1.14	1.46	1.77	3.05	0.617
Age	1.06	1.54	0.00	0.51	0.59	0.72	0.91	1.18	1.61	2.03	3.59	0.604
Age/I	1.07	1.34	0.00	0.55	0.63	0.76	0.94	1.19	1.56	1.93	3.34	0.577
Panel B: Capital preservation strategy												
Bills	0.71	1.07	0.00	0.44	0.50	0.58	0.67	0.79	0.93	1.07	1.74	0.930
Panel C: Equity strategies												
Stocks	1.20	1.50	0.00	0.50	0.59	0.73	0.96	1.33	1.96	2.61	5.03	0.537
Stocks/I	1.24	1.38	0.00	0.58	0.67	0.82	1.05	1.39	1.94	2.49	4.62	0.452

TABLE VII: RETIREMENT-PERIOD DRAWDOWN

The table summarizes the distribution of the maximum portfolio drawdown during the post-retirement period across 1,000,000 bootstrap simulations for households adopting various asset allocation strategies. Household income in the pre-retirement period is stochastic and follows the process estimated by Guvenen, Karahan, Ozkan, and Song (2021). The household's savings rate in the pre-retirement period is 10%. Household income in the post-retirement period is the sum of Social Security income and a constant real withdrawal of 4% of the household's investment account value at retirement (as long as the account has not been depleted). The household faces uncertainty over labor income, investment returns, and longevity. For each asset allocation strategy, the table reports the mean, standard deviation, and distribution percentiles of the maximum portfolio drawdown.

	Moments		Percentiles								
Strategy	Mean	StDev	1%	5%	10%	25%	50%	75%	90%	95%	99%
Panel A: Safe harbor strategies											
TDF	0.38	0.23	0.00	0.09	0.13	0.20	0.32	0.52	0.74	0.86	0.97
Balanced	0.49	0.22	0.00	0.16	0.23	0.33	0.46	0.64	0.82	0.90	0.98
Balanced/I	0.40	0.20	0.00	0.12	0.18	0.27	0.38	0.52	0.68	0.79	0.93
Age	0.47	0.24	0.00	0.14	0.19	0.29	0.43	0.63	0.83	0.91	0.99
Age/I	0.38	0.21	0.00	0.11	0.15	0.23	0.33	0.50	0.69	0.81	0.95
Panel B: Capital preservation strategy											
Bills	0.43	0.30	0.00	0.03	0.06	0.17	0.38	0.65	0.91	0.97	0.99
Panel C: Equity strategies											
Stocks	0.63	0.22	0.00	0.26	0.35	0.50	0.64	0.78	0.91	0.96	0.99
Stocks/I	0.50	0.18	0.00	0.18	0.26	0.39	0.53	0.62	0.71	0.77	0.91

Table VIII: Wealth at death

The table summarizes the distribution of real wealth at death across 1,000,000 bootstrap simulations for households adopting various asset allocation strategies. Household income in the pre-retirement period is stochastic and follows the process estimated by Guvenen, Karahan, Ozkan, and Song (2021). The household's savings rate in the pre-retirement period is 10%. Household income in the post-retirement period is the sum of Social Security income and a constant real withdrawal of 4% of the household's investment account value at retirement (as long as the account has not been depleted). The household faces uncertainty over labor income, investment returns, and longevity. For each asset allocation strategy, the table reports the mean, standard deviation, and distribution percentiles of real wealth at death of the last survivor in millions of 2022 USD. The last column in the table shows the proportion of simulations in which the household depletes its investment account prior to the death of the last survivor.

	Moments		Percentiles									
Strategy	Mean	StDev	1%	5%	10%	25%	50%	75%	90%	95%	99%	$\mathbb{E}[\mathbf{1}_R]$
Panel A: Safe harbor strategies												
TDF	0.86	5.12	0.00	0.00	0.00	0.08	0.35	0.89	1.86	2.87	6.84	0.169
Balanced	1.30	9.31	0.00	0.00	0.00	0.09	0.42	1.16	2.71	4.52	12.53	0.157
Balanced/I	1.26	7.27	0.00	0.00	0.00	0.17	0.52	1.23	2.58	4.08	10.63	0.109
Age	1.15	8.70	0.00	0.00	0.00	0.08	0.39	1.06	2.43	3.97	10.48	0.168
Age/I	1.10	6.54	0.00	0.00	0.00	0.13	0.46	1.12	2.31	3.60	8.91	0.133
Panel B: Capital preservation strategy												
Bills	0.09	0.15	0.00	0.00	0.00	0.00	0.03	0.12	0.26	0.37	0.68	0.357
Panel C: Equity strategies												
Stocks	2.81	13.53	0.00	0.00	0.00	0.10	0.61	2.05	5.71	10.58	34.95	0.174
Stocks/I	2.97	11.70	0.00	0.00	0.04	0.33	1.01	2.62	6.19	10.60	31.46	0.082

TABLE IX: ECONOMIC VALUE OF ALTERNATIVE INVESTMENT PLANS

The table reports equivalent savings rates to quantify relative economic value in pairwise comparisons of asset allocation strategies. Each comparison is based on expected household utility over retirement consumption and bequest across 1,000,000 bootstrap simulations. Household income in the pre-retirement period is stochastic and follows the process estimated by Guvenen, Karahan, Ozkan, and Song (2021). The household's savings rate for the base strategy in the pre-retirement period is 10%. The table reports the household's savings rate for the alternative strategy. This value equates the expected utility from retirement consumption and bequest for the two strategies. For each strategy, household income in the post-retirement period is the sum of Social Security income and a constant real withdrawal of 4% of the household's investment account value at retirement (as long as the account has not been depleted). The household faces uncertainty over labor income, investment returns, and longevity.

	Alternative strategy							
Base strategy	TDF	Balanced	Balanced/I	Age	Age/I	Bills	Stocks	Stocks/I
Panel A: Safe harbor strategies								
TDF	—	11.8%	10.1%	11.1%	9.4%	31.5%	10.5%	7.2%
Balanced	8.5%	—	8.7%	9.4%	8.1%	26.4%	8.8%	6.2%
Balanced/I	9.8%	11.7%	—	11.0%	9.3%	31.1%	10.4%	7.1%
Age	9.0%	10.6%	9.2%	—	8.6%	28.1%	9.3%	6.5%
Age/I	10.6%	12.5%	10.7%	11.8%	—	33.6%	11.2%	7.6%
Panel B: Capital preservation strategy								
Bills	3.3%	3.8%	3.5%	3.5%	3.2%	—	3.1%	2.4%
Panel C: Equity strategies								
Stocks	9.6%	11.3%	9.7%	10.7%	9.1%	30.0%	—	6.9%
Stocks/I	14.1%	16.9%	14.0%	16.0%	13.2%	46.9%	15.6%	—

Table X: Estimated financial ruin probabilities

The table reports the estimated likelihood of financial ruin across 1,000,000 bootstrap simulations for households adopting various asset allocation strategies. Each simulation corresponds to a specific underlying data sample (i.e., the pooled sample of developed countries or the US sample) and bootstrap sampling approach (i.e., a block bootstrap with an average block length of 120 months or an IID bootstrap). Household income in the pre-retirement period is stochastic and follows the process estimated by Guvenen, Karahan, Ozkan, and Song (2021). The household's savings rate in the pre-retirement period is 10%. Household income in the post-retirement period is the sum of Social Security income and a constant real withdrawal of 4% of the household's investment account value at retirement (as long as the account has not been depleted). The household faces uncertainty over labor income, investment returns, and longevity. Financial ruin is defined as the proportion of simulations in which the household depletes its investment account prior to the death of the last survivor.

	Strategy							
Bootstrap design	TDF	Balanced	Balanced/I	Age	Age/I	Bills	Stocks	Stocks/I
Panel A: Developed sample								
Block bootstrap	0.169	0.157	0.109	0.168	0.133	0.357	0.174	0.082
IID bootstrap	0.122	0.121	0.065	0.129	0.084	0.421	0.157	0.067
Panel B: US sample								
Block bootstrap	0.107	0.045	0.062	0.060	0.080	0.308	0.050	0.052
IID bootstrap	0.052	0.039	0.033	0.041	0.039	0.297	0.066	0.048

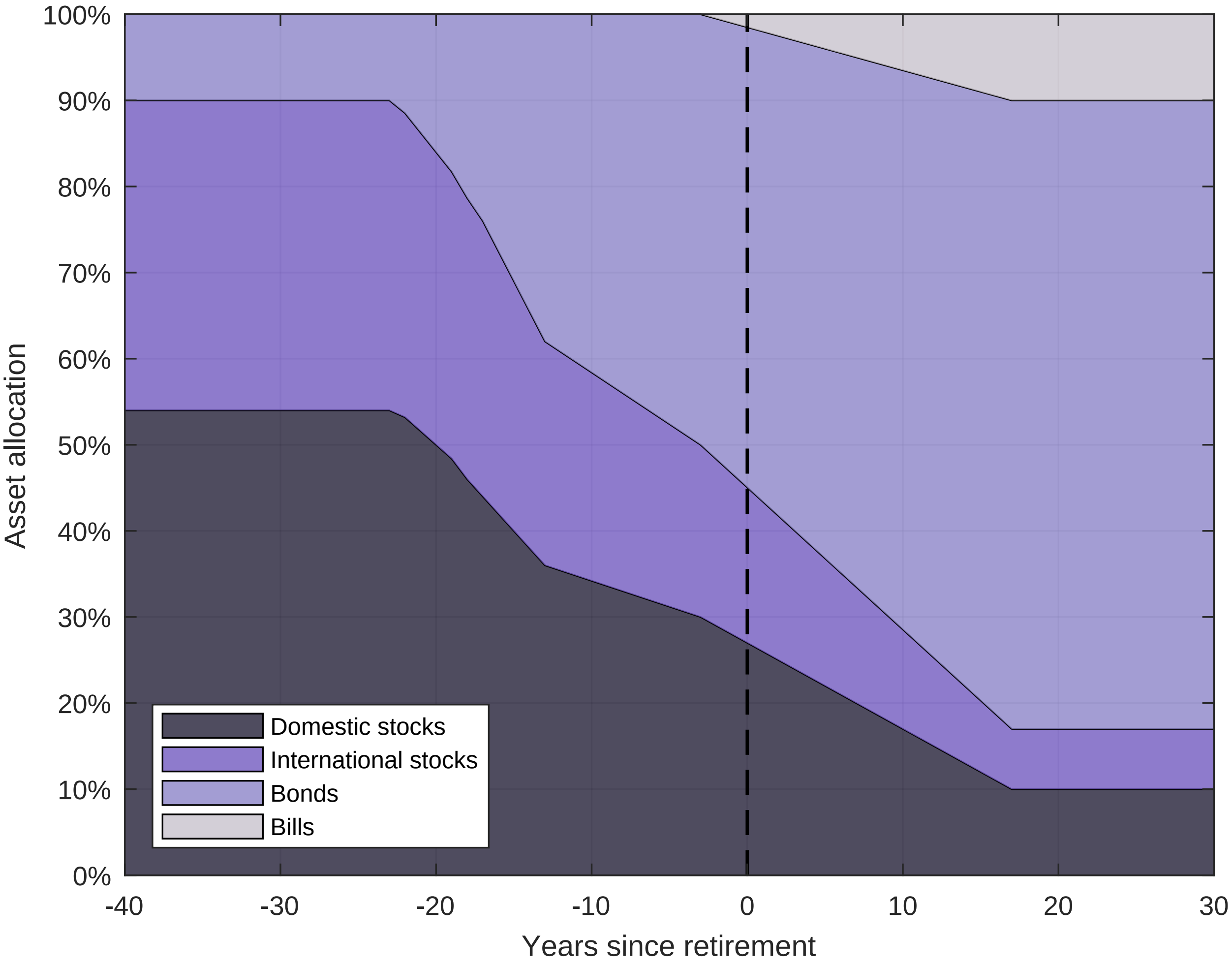


Figure 1. Glidepath weights for target-date fund. The figure shows the asset allocation of the target-date strategy as a function of time since retirement. The strategy invests in domestic stocks, international stocks, bonds, and bills.

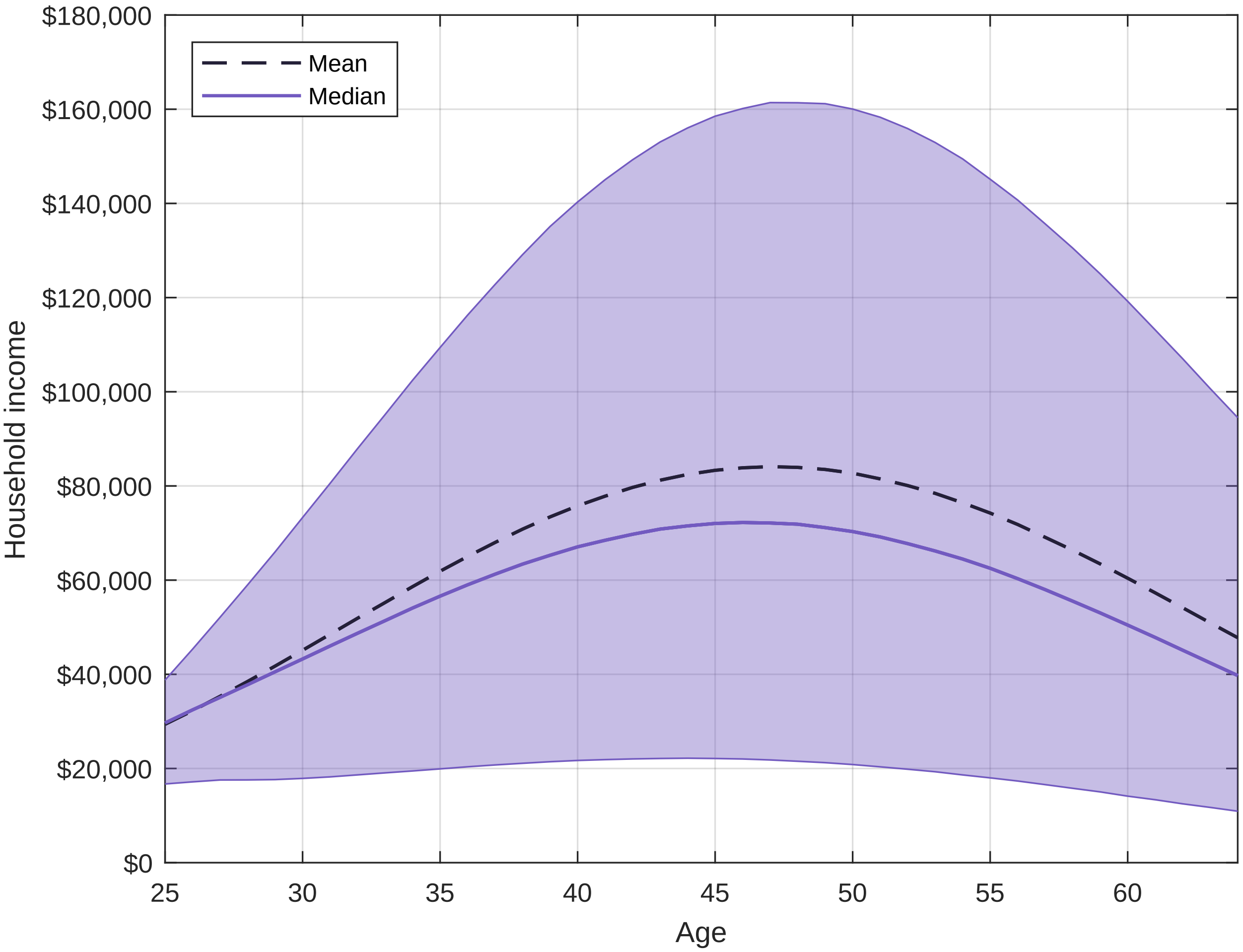


Figure 2. Distribution of household income. The figure shows the distribution of real household income across 1,000,000 bootstrap simulations in 2022 USD as a function of age. Household income is stochastic and follows the process estimated by Guvenen, Karahan, Ozkan, and Song (2021) with an initial income parameter of $z_0^i = 0$ and human capital parameters of $(\alpha^i, \beta^i) = (0, 0)$. The solid (dashed) line corresponds to the median (mean) household income as a function of age. The shaded region covers the 10th through 90th percentiles of the distribution.

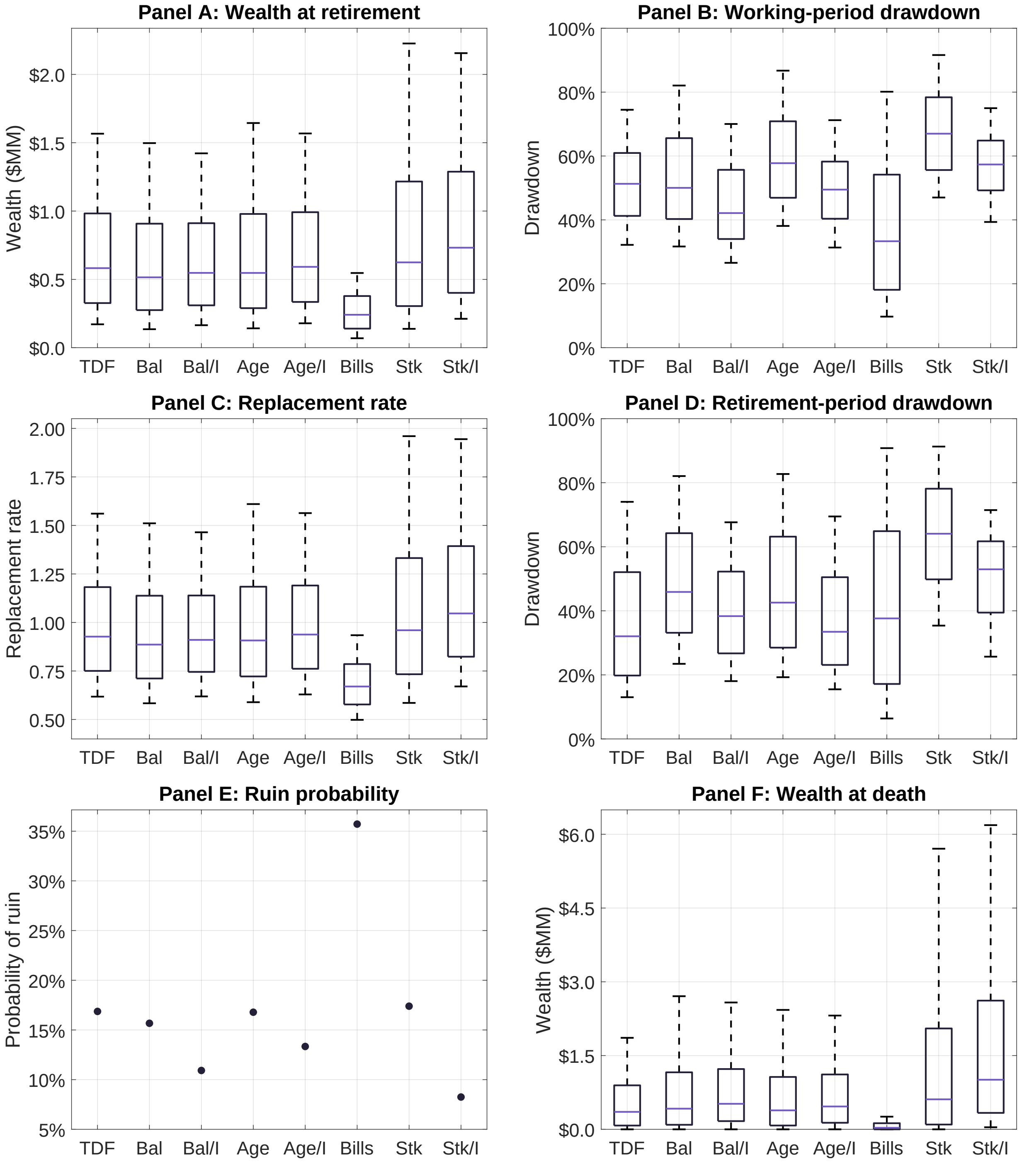


Figure 3. Measures of investment performance. The figure summarizes the distribution of real wealth at retirement (Panel A), the distribution of the working-period drawdown (Panel B), the distribution of the real income replacement rate (Panel C), the distribution of the retirement-period drawdown (Panel D), the probability of financial ruin (Panel E), and the distribution of real wealth at death (Panel F) across 1,000,000 bootstrap simulations for households adopting various asset allocation strategies. In each box-and-whiskers plot, the middle line corresponds to the median, the box covers the interquartile range, and the whiskers cover the 10th through 90th percentiles.

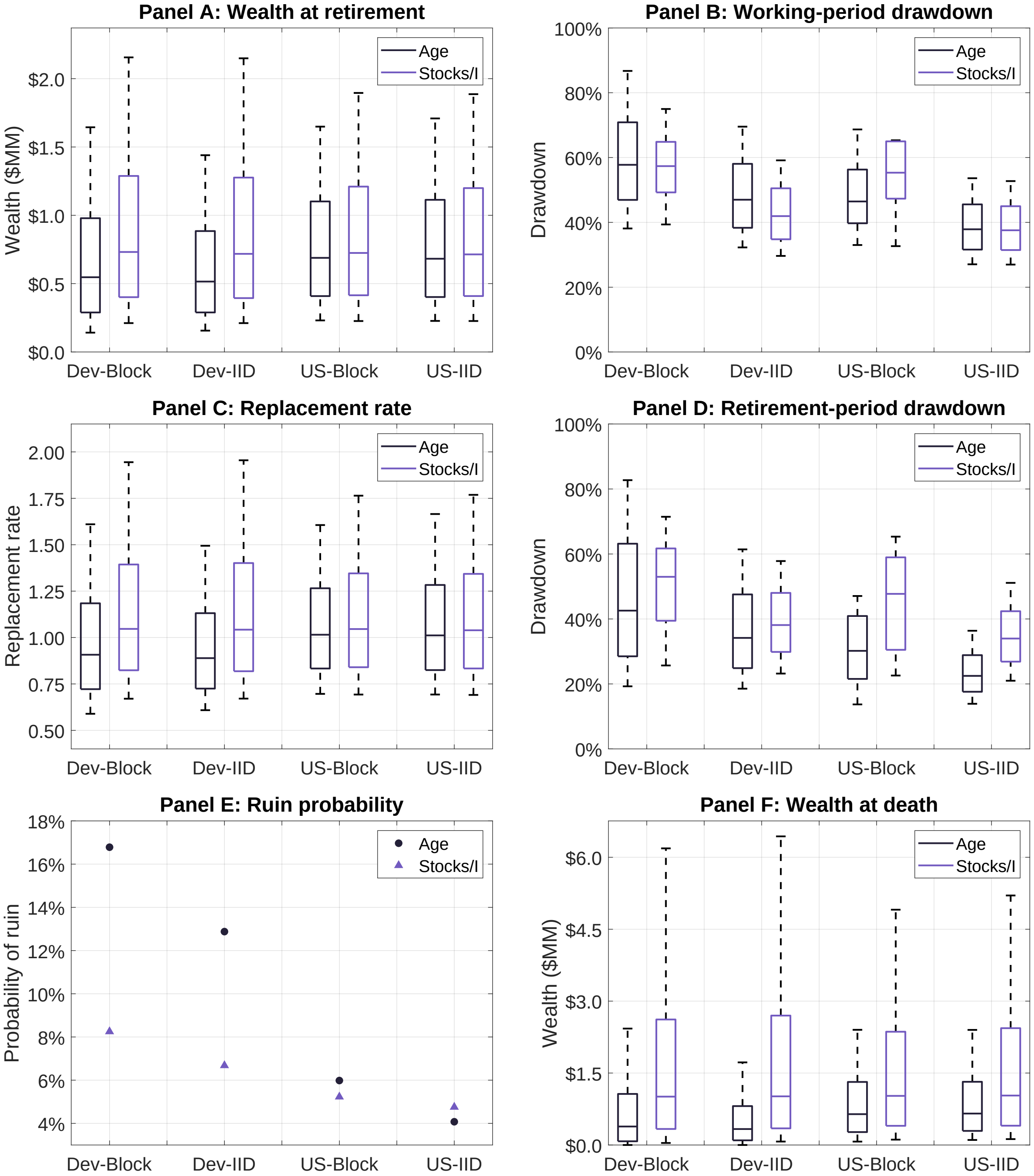


Figure 4. Measures of investment performance: Alternative samples and bootstrap specifications. The figure summarizes the distribution of real wealth at retirement (Panel A), the distribution of the working-period drawdown (Panel B), the distribution of the real income replacement rate (Panel C), the distribution of the retirement-period drawdown (Panel D), the probability of financial ruin (Panel E), and the distribution of real wealth at death (Panel F) across 1,000,000 bootstrap simulations for households adopting the Age and Stocks/I asset allocation strategies. Each simulation corresponds to a specific underlying data sample (i.e., the pooled sample of developed countries or the US sample) and bootstrap sampling approach (i.e., a block bootstrap with an average block length of 120 months or an IID bootstrap). In each box-and-whiskers plot, the middle line corresponds to the median, the box covers the interquartile range, and the whiskers cover the 10th through 90th percentiles.

INTERNET APPENDIX

Beyond the Status Quo: A Critical Assessment of Lifecycle Investment Advice

September 26, 2023

Abstract

This internet appendix contains material that is supplemental to the paper "Beyond the Status Quo: A Critical Assessment of Lifecycle Investment Advice."

A Social Security benefits calculations

We compute Social Security benefit payments using the formulas effective in 2022. Given that Social Security formulas are inflation-indexed, all of our calculations use real 2022 dollars. As such, the amount subject to Social Security taxes for each year in the investor's working life is the minimum of annual income and \$147,000, which is the maximum taxable earnings. The average indexed monthly earnings (AIME) for each investor is the average of their highest 35 years of taxed earnings divided by 12. An investor who retires at the normal retirement age of 67 has a personal Social Security benefit according to a formula that sums 90% of AIME up to \$1,024, 32% of AIME between \$1,024 and \$6,172, and 15% of AIME in excess of \$6,172. This retirement benefit is reduced by (5/9)% per month of early retirement up to 36 months and further reduced by (5/12)% per month of early retirement between ages 62 (the earliest allowed retirement age) and 64 (normal retirement age minus 36 months). The retirement benefit increases by (2/3)% per month of late retirement between ages 67 and 70 (the latest allowed retirement age).

Spouses may be eligible for additional benefits under the Social Security system. In our specifications in which all investors have mean income, each retiree optimally takes their own retirement benefit during their retirement years. In those with random incomes from the model of Guvenen, Karahan, Ozkan, and Song (2021), some investors may optimally choose to take spousal and/or survivor benefits. When both members of the couple are living, each spouse has the option to take half of their spouse's personal retirement benefit as a spousal benefit in lieu of taking their own retirement benefit. This option becomes useful if one of the two household members earns substantially more than the other during their working years. The spousal benefit is reduced by (25/36)% per month of early retirement up to 36 months and further reduced by (5/12)% per month between ages 62 and 64. Upon the death of one spouse, the surviving spouse qualifies for a survivor benefit. The potential survivor benefit is the personal benefit of the deceased spouse if the surviving spouse is full retirement age. If not, the survivor benefit is reduced by up to 28.5% (if taken before age 60). The surviving spouse may take the larger of their personal retirement benefit and their survivor benefit.

Finally, the SSA administers the Supplemental Security Income (SSI) program, which provides payments to retirees (and certain other individuals) who have little income from other sources. SSI payments are reduced by earnings, and the maximum monthly benefit amounts in 2022 are \$1,261 for couples and \$841 for singles. In our specifications with mean income investors, no retirees qualify for SSI because their Social Security benefits exceed the SSI thresholds. In the random income specifications, we impose minimum monthly consumption levels of \$1,261 for couples and \$841 for singles to reflect SSI payments for investors who earn little enough during their working years that their retirement income from Social Security and savings falls below these levels. This modeling choice reflects the social safety net and avoids issues with computing utility when consumption levels are zero or low.

B Supplementary results

This appendix reports supplementary empirical results.

B.1 Conditional results

Figures B.1 to B.3 show results conditional on outcomes for important variables. Figure B.1 conditions on realized cumulative inflation and presents results for each quintile. Panels A (wealth at retirement) and B (working-period drawdown) condition on cumulative inflation during the working years, and Panels D (retirement-period drawdown) and E (ruin probability) condition on cumulative inflation during the retirement years. Panels C (replacement rate) and F (wealth at death) condition on cumulative inflation during the full life given that these outcomes depend on both working-period and retirement-period realizations. Figure B.2 presents results conditional on realized household longevity. Figure B.3 conditions on realized cumulative real domestic stock returns. The timing of the stock return realizations used for each panel is analogous to that from Figure B.1.

B.2 Household heterogeneity

The base results in the paper correspond to a median investor with $(\alpha^i, \beta^i, z_0^i) = (0, 0, 0)$. We specify four additional investor types with differing levels of human capital (α^i, β^i) and initial income (z_0^i). Low human capital types have α^i and β^i at the 10th percentile of their distributions, and high human capital types are at the 90th percentile. Similarly, low initial income types have z_0^i at the 10th percentile and high initial income types are at the 90th percentile. For simplicity, we assume the female and male in each couple share the same type.

Figure B.4 shows the lifecycle savings profile for each investor type. The figure specifically reports the average across draws of the percentage of lifetime savings that occurs within five-year age ranges during the working period.

Figure B.5 plots distributions of Social Security contributions and benefits by investor type. Panel A shows distributions of the sum across the female and male of the number of working years that contribute to the average indexed monthly earnings in the Social Security formula (capped at 35 years per worker). Deviations from 70 reflect nonemployment. Panel B reports the average taxable income (capped at \$147,000 per worker per year) across all years that contribute to the average indexed monthly earnings in the Social Security formula. Panel C shows the annual Social Security benefit for the household, averaged across years with at least one living household member. Panel D reports the average proportion of retirement income that comes from Social Security, where the remainder of income comes from retirement account withdrawals assuming the asset allocation of the TDF strategy.

Figures B.6 to B.8 plot distributions of wealth at retirement, income replacement rates, and wealth at death, respectively, for each investor type. Drawdowns and ruin probabilities for each investor type are identical to the base case in the paper due to the structure of the lifecycle design.

B.3 Alternative static-weight portfolio strategies

Table B.I reports equivalent savings rates of all-equity strategies that have different weights in domestic versus international stocks. The Stocks/I strategy allocates 50% to domestic stocks and 50% to international stocks. The table shows savings rates corresponding to domestic stock allocations ranging from 5% to 50%, with the remainder invested in international stocks. Each row reports a couple's base strategy and each column shows an alternative strategy.

Table B.II reports equivalent savings rates of strategies with different allocations to bonds. The equity portion of each strategy is allocated half to domestic stocks and half to international stocks. Each row reports a couple's base strategy and each column shows an alternative strategy. Panel A shows strategies with constant portfolio weights throughout the couple's lifespan. The Stocks/I strategy has 0% bonds and the Balanced/I strategy has 40% bonds. The panel shows bond allocations ranging from 0% to 40%. Panel B reports results for strategies that first allocate 50% to domestic stocks and 50% to international stocks during the working years, then allocate some portion to bonds during retirement with the equity portion allocated half to domestic stocks and half to international stocks. The panel shows strategies with post-retirement bond allocations ranging from 0% to 40%.

B.4 Alternative portfolio withdrawal policies

The base design in the paper uses the 4% rule to calculate retirement-period withdrawals from retirement savings. Figures B.9 and B.10 show results for an analogous 3% rule and 5% rule, respectively. Figure B.11 plots outcomes for a couple who withdraws in each month an annualized 4% of the current investment account balance.

B.5 Alternative samples and bootstrap specifications

Figure 4 of the paper reports results for the Age and Stocks/I strategies from each of four method designs. The base case in Figure 3 of the paper uses the Dev-Block approach. Figures B.12 to B.14 plot outcomes for all eight investment strategies using the Dev-IID, US-Block, and US-IID approaches, respectively.

TABLE B.I: ECONOMIC VALUE OF ALTERNATIVE INVESTMENT PLANS WITH FIXED WEIGHTS ACROSS DOMESTIC AND INTERNATIONAL STOCKS

The table reports equivalent savings rates to quantify relative economic value in pairwise comparisons of asset allocation strategies with fixed weights across domestic and international stocks. In the table, Each strategy is defined by its weight in domestic stocks. Each comparison is based on expected household utility over retirement consumption and bequest across 1,000,000 bootstrap simulations. Household income in the pre-retirement period is stochastic and follows the process estimated by Guvenen, Karahan, Ozkan, and Song (2021). The household's savings rate for the base strategy in the pre-retirement period is 10%. The table reports the household's savings rate for the alternative strategy. This value equates the expected utility from retirement consumption and bequest for the two strategies. For each strategy, household income in the post-retirement period is the sum of Social Security income and a constant real withdrawal of 4% of the household's investment account value at retirement (as long as the account has not been depleted). The household faces uncertainty over labor income, investment returns, and longevity.

	Alternative strategy (allocation to domestic stocks)									
Base strategy	5%	10%	15%	20%	25%	30%	35%	40%	45%	(Stocks/I) 50%
5%	—	9.8%	9.6%	9.4%	9.3%	9.3%	9.2%	9.3%	9.3%	9.4%
10%	10.2%	—	9.8%	9.6%	9.5%	9.5%	9.5%	9.5%	9.6%	9.7%
15%	10.5%	10.2%	—	9.8%	9.7%	9.7%	9.7%	9.7%	9.7%	9.9%
20%	10.6%	10.4%	10.2%	—	9.9%	9.8%	9.8%	9.8%	9.9%	10.0%
25%	10.8%	10.5%	10.3%	10.1%	—	9.9%	9.9%	9.9%	10.0%	10.1%
30%	10.8%	10.6%	10.3%	10.2%	10.1%	—	10.0%	10.0%	10.1%	10.2%
35%	10.8%	10.6%	10.3%	10.2%	10.1%	10.0%	—	10.0%	10.1%	10.2%
40%	10.8%	10.5%	10.3%	10.2%	10.1%	10.0%	10.0%	—	10.1%	10.2%
45%	10.7%	10.5%	10.3%	10.1%	10.0%	9.9%	9.9%	9.9%	—	10.1%
50% (Stocks/I)	10.6%	10.3%	10.1%	10.0%	9.9%	9.8%	9.8%	9.8%	9.9%	—

TABLE B.II:

ECONOMIC VALUE OF ALTERNATIVE INVESTMENT PLANS WITH FIXED WEIGHTS ACROSS DOMESTIC STOCKS, INTERNATIONAL STOCKS, AND BONDS

The table reports equivalent savings rates to quantify relative economic value in pairwise comparisons of asset allocation strategies with fixed weights across domestic stocks, international stocks, and bonds. The stock allocation for each strategy is split evenly between domestic stocks and international stocks. In the table, each strategy is defined by its weight in bonds. The strategies in Panel A adopt the indicated allocation to bonds over the full lifecycle. The strategies in Panel B have zero allocation to bonds in the pre-retirement period and adopt the indicated allocation to bonds in the post-retirement period. Each comparison is based on expected household utility over retirement consumption and bequest across 1,000,000 bootstrap simulations. Household income in the pre-retirement period is stochastic and follows the process estimated by Guvenen, Karahan, Ozkan, and Song (2021). The household's savings rate for the base strategy in the pre-retirement period is 10%. The table reports the household's savings rate for the alternative strategy. This value equates the expected utility from retirement consumption and bequest for the two strategies. For each strategy, household income in the post-retirement period is the sum of Social Security income and a constant real withdrawal of 4% of the household's investment account value at retirement (as long as the account has not been depleted). The household faces uncertainty over labor income, investment returns, and longevity.

	Alternative strategy (allocation to bonds)								
Base strategy	(Stocks/I) 0%	5%	10%	15%	20%	25%	30%	35%	40%
Panel A: Allocation to bonds over the full lifecycle									
0% (Stocks/I)	—	10.3%	10.6%	11.0%	11.5%	12.0%	12.6%	13.2%	14.0%
5%	9.7%	—	10.3%	10.7%	11.2%	11.7%	12.3%	12.9%	13.6%
10%	9.4%	9.7%	—	10.4%	10.8%	11.3%	11.9%	12.5%	13.2%
15%	9.1%	9.3%	9.6%	—	10.4%	10.9%	11.4%	12.0%	12.7%
20%	8.7%	8.9%	9.2%	9.6%	—	10.5%	11.0%	11.5%	12.1%
25%	8.3%	8.5%	8.8%	9.1%	9.6%	—	10.5%	11.0%	11.6%
30%	7.9%	8.1%	8.4%	8.8%	9.1%	9.5%	—	10.5%	11.1%
35%	7.5%	7.8%	8.0%	8.3%	8.7%	9.1%	9.5%	—	10.5%
40% (Balanced/I)	7.1%	7.3%	7.6%	7.9%	8.2%	8.6%	9.0%	9.5%	—
Panel B: Allocation to bonds in the post-retirement period only									
0% (Stocks/I)	—	10.0%	10.0%	10.0%	10.0%	10.1%	10.2%	10.2%	10.3%
5%	10.0%	—	10.0%	10.0%	10.1%	10.1%	10.2%	10.3%	10.4%
10%	10.0%	10.0%	—	10.0%	10.1%	10.1%	10.2%	10.2%	10.3%
15%	10.0%	10.0%	10.0%	—	10.0%	10.1%	10.1%	10.2%	10.3%
20%	10.0%	9.9%	9.9%	10.0%	—	10.1%	10.1%	10.2%	10.3%
25%	9.9%	9.9%	9.9%	9.9%	10.0%	—	10.1%	10.1%	10.2%
30%	9.8%	9.8%	9.8%	9.9%	9.9%	9.9%	—	10.1%	10.2%
35%	9.8%	9.8%	9.8%	9.8%	9.8%	9.9%	9.9%	—	10.1%
40%	9.7%	9.7%	9.7%	9.7%	9.7%	9.8%	9.8%	9.9%	—

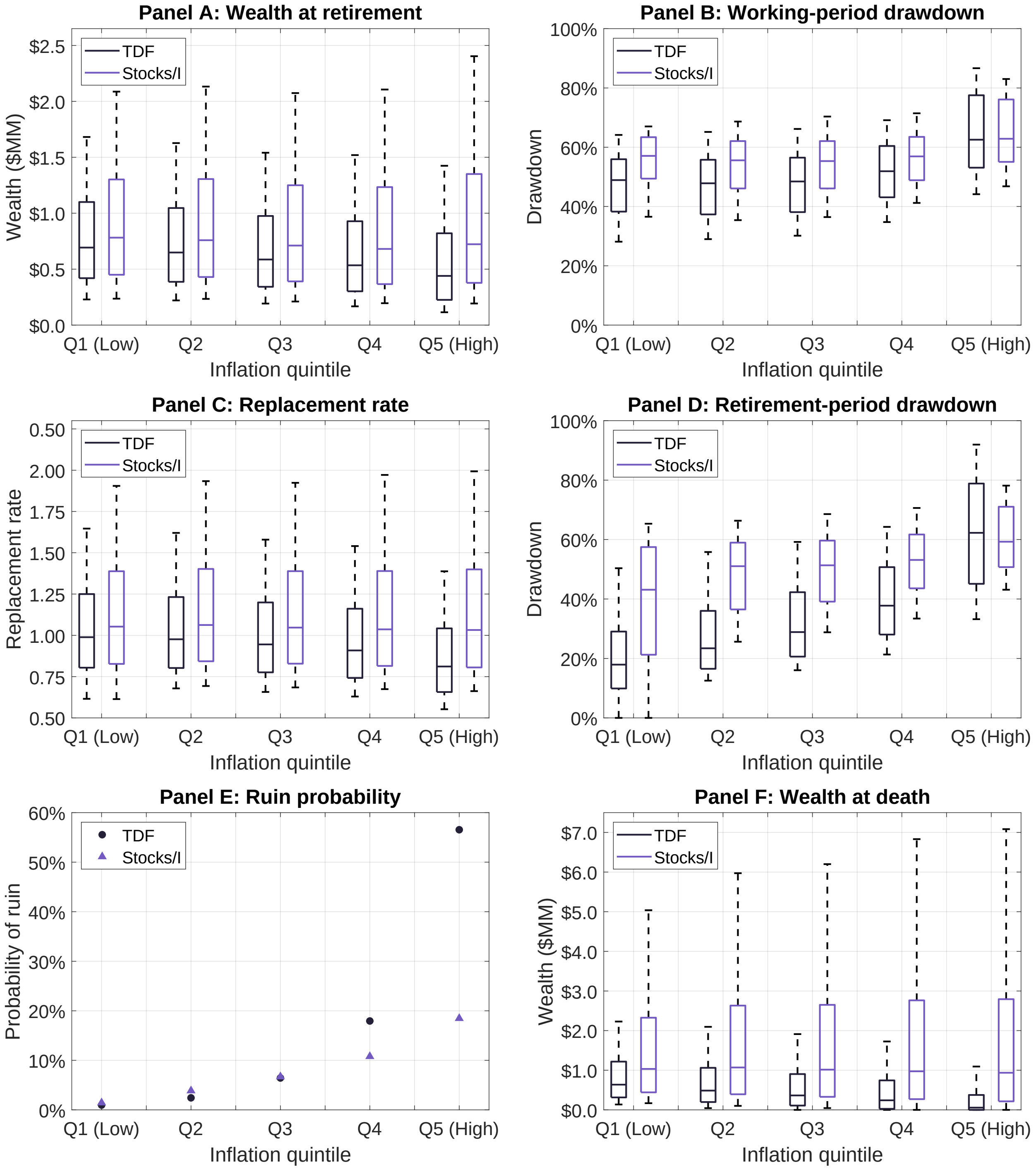


Figure B.1. Measures of investment performance conditional on realized inflation. The figure summarizes the distribution of real wealth at retirement (Panel A), the distribution of the working-period drawdown (Panel B), the distribution of the real income replacement rate (Panel C), the distribution of the retirement-period drawdown (Panel D), the probability of financial ruin (Panel E), and the distribution of real wealth at death (Panel F) conditional on quintile outcomes of inflation across 1,000,000 bootstrap simulations for households adopting the TDF and Stocks/I asset allocation strategies. The outcomes in Panels A and B (Panels D and E) {Panels C and F} condition on realized inflation during the pre-retirement period (post-retirement period) {entire lifecycle}. In each box-and-whiskers plot, the middle line corresponds to the median, the box covers the interquartile range, and the whiskers cover the 10th through 90th percentiles.

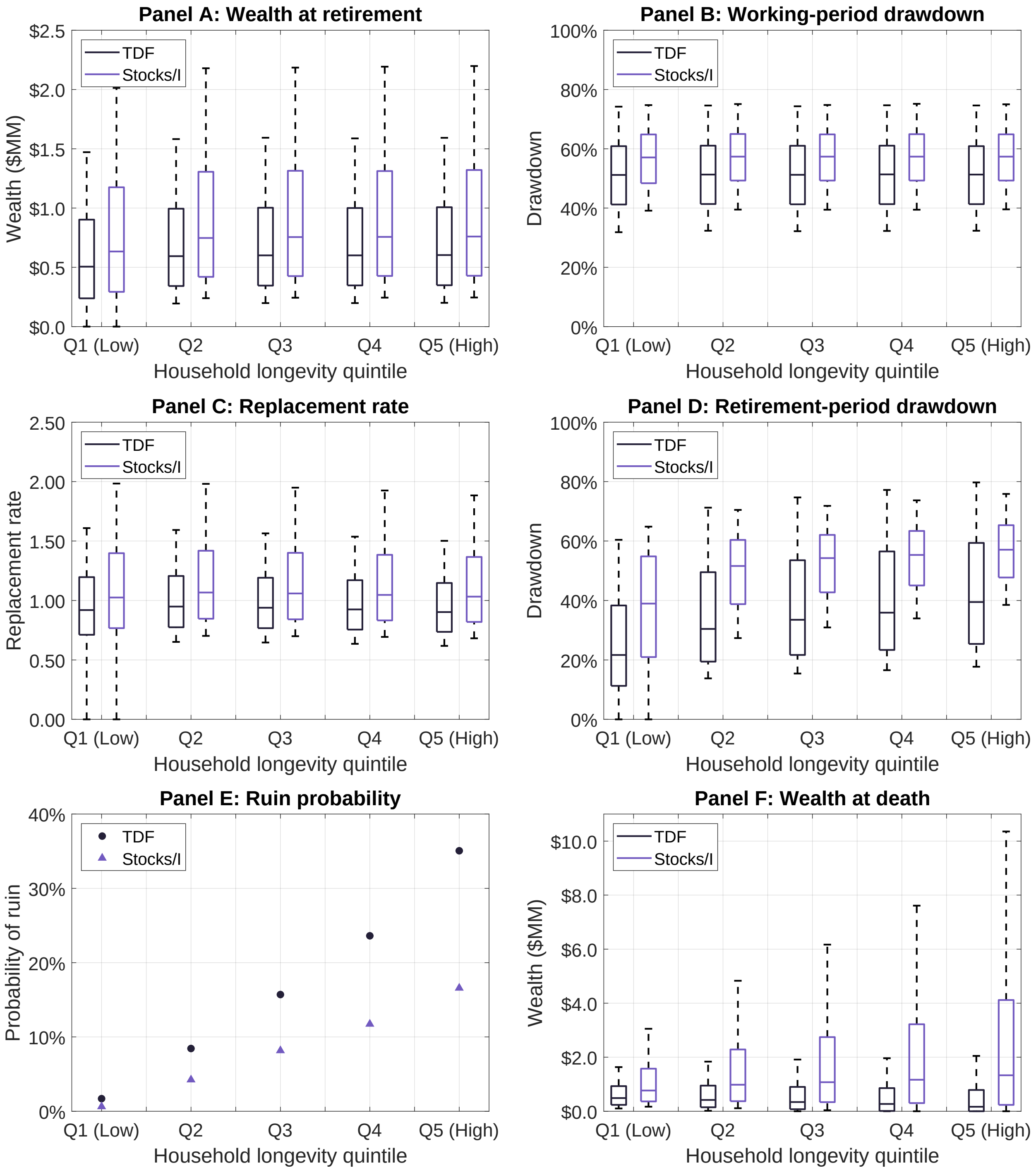


Figure B.2. Measures of investment performance conditional on household longevity. The figure summarizes the distribution of real wealth at retirement (Panel A), the distribution of the working-period drawdown (Panel B), the distribution of the real income replacement rate (Panel C), the distribution of the retirement-period drawdown (Panel D), the probability of financial ruin (Panel E), and the distribution of real wealth at death (Panel F) conditional on quintile outcomes of household longevity across 1,000,000 bootstrap simulations for households adopting the TDF and Stocks/I asset allocation strategies. In each box-and-whiskers plot, the middle line corresponds to the median, the box covers the interquartile range, and the whiskers cover the 10th through 90th percentiles.

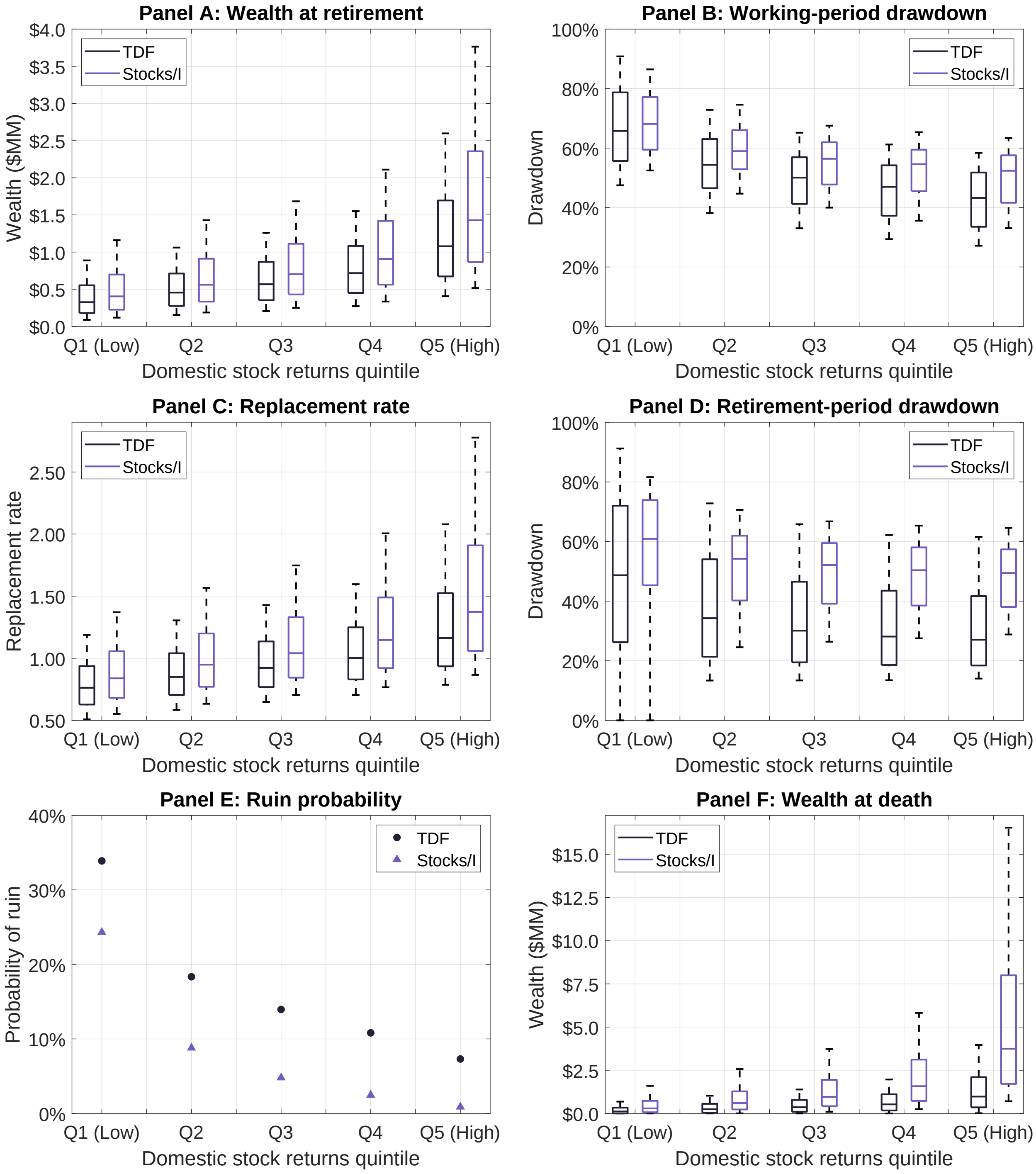


Figure B.3. Measures of investment performance conditional on realized domestic stock returns. The figure summarizes the distribution of real wealth at retirement (Panel A), the distribution of the working-period drawdown (Panel B), the distribution of the real income replacement rate (Panel C), the distribution of the retirement-period drawdown (Panel D), the probability of financial ruin (Panel E), and the distribution of real wealth at death (Panel F) conditional on quintile outcomes of realized returns for domestic stocks across 1,000,000 bootstrap simulations for households adopting the TDF and Stocks/I asset allocation strategies. In each box-and-whiskers plot, the middle line corresponds to the median, the box covers the interquartile range, and the whiskers cover the 10th through 90th percentiles.

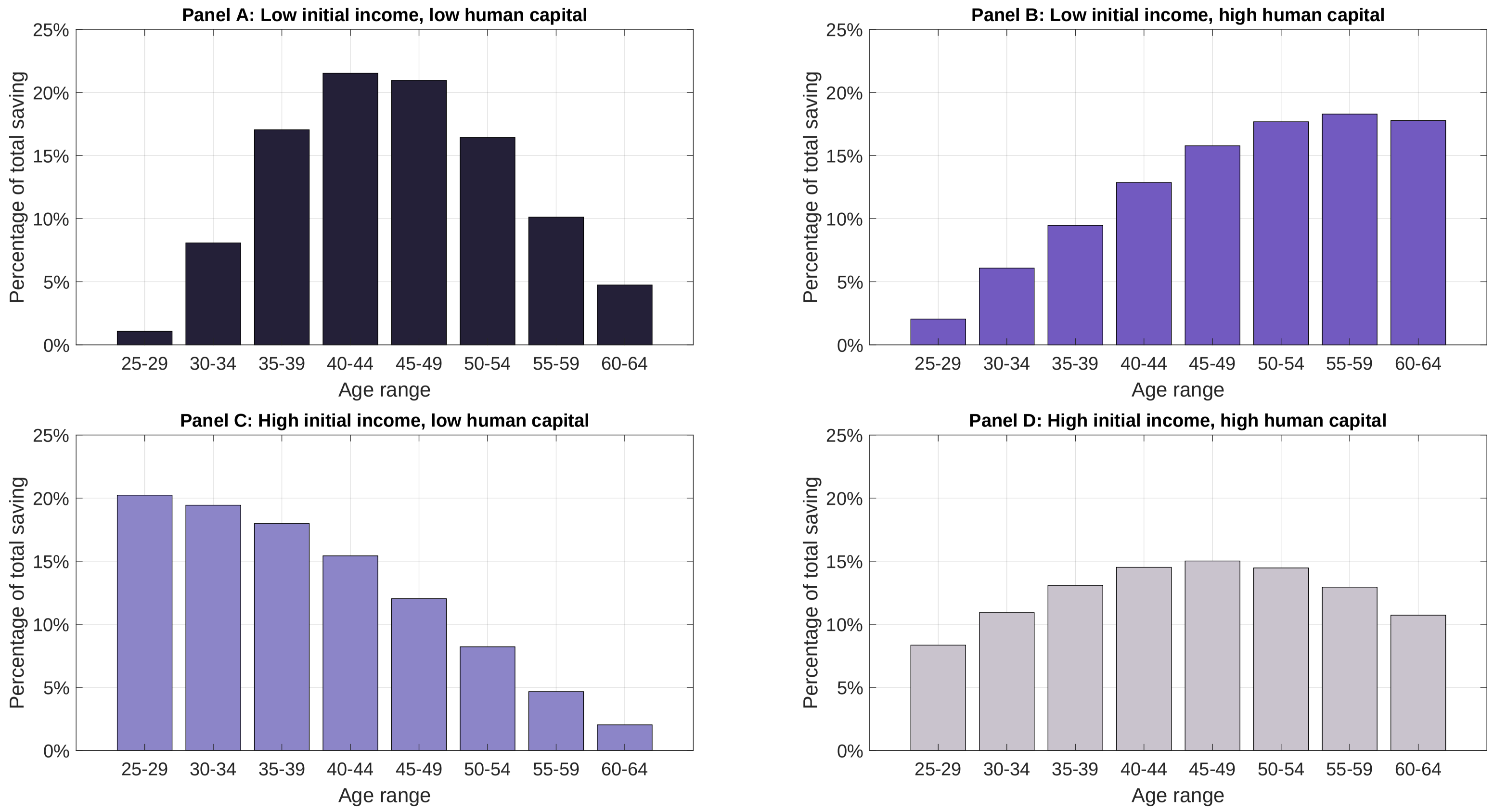
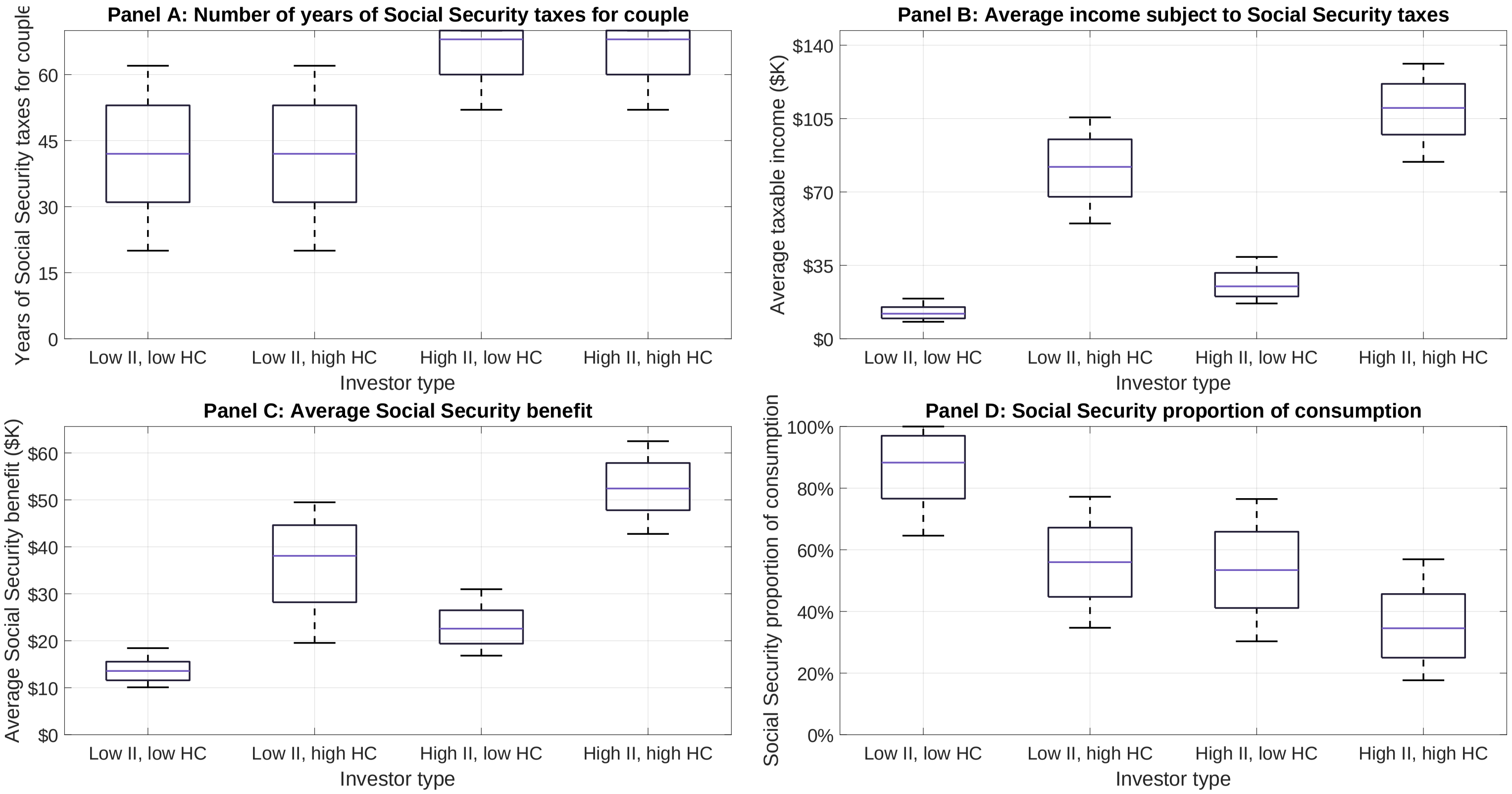


Figure B.4. Lifecycle saving profiles by investor type. The figure summarizes the concentration of household retirement saving throughout the lifecycle across 1,000,000 bootstrap simulations. Each panel of the figure corresponds to specific values for initial income (z_0^i) and human capital parameters (α^i, β^i). Each bar in a given panel shows the average percentage of total real lifetime saving that occurs over the corresponding age range. Household income in the pre-retirement period is stochastic and follows the process estimated by Guvenen, Karahan, Ozkan, and Song (2021). The household's savings rate in the pre-retirement period is 10%.


Panel A: Number of years of Social Security taxes for couple

Panel B: Average income subject to Social Security taxes

Panel C: Average Social Security benefit

Panel D: Social Security proportion of consumption

FIGURE B.5. SOCIAL SECURITY BENEFITS BY INVESTOR TYPE. The figure summarizes several features of Social Security benefits for various household types across 1,000,000 bootstrap simulations. Each panel of the figure presents distributions for four investor types based on initial income (z_0^i) and human capital parameters (α^i, β^i). Panel A shows the distribution of the number of total working years (capped at 70 for the couple) that contribute to average indexed monthly earnings in the Social Security benefit formula. Panel B shows the distribution of average individual income (capped at the Social Security maximum taxable earnings of $147,000) over the years corresponding to the distribution in Panel A. Panel C shows the distribution of average annual household Social Security benefits and Supplemental Security Income. Panel D shows the distribution of the average annual ratio of household Social Security benefits and Supplemental Security Income to total consumption. The asset allocation strategy used to construct Panel D is the TDF strategy. In each box-and-whiskers plot, the middle line corresponds to the median, the box covers the interquartile range, and the whiskers cover the 10th through 90th percentiles.

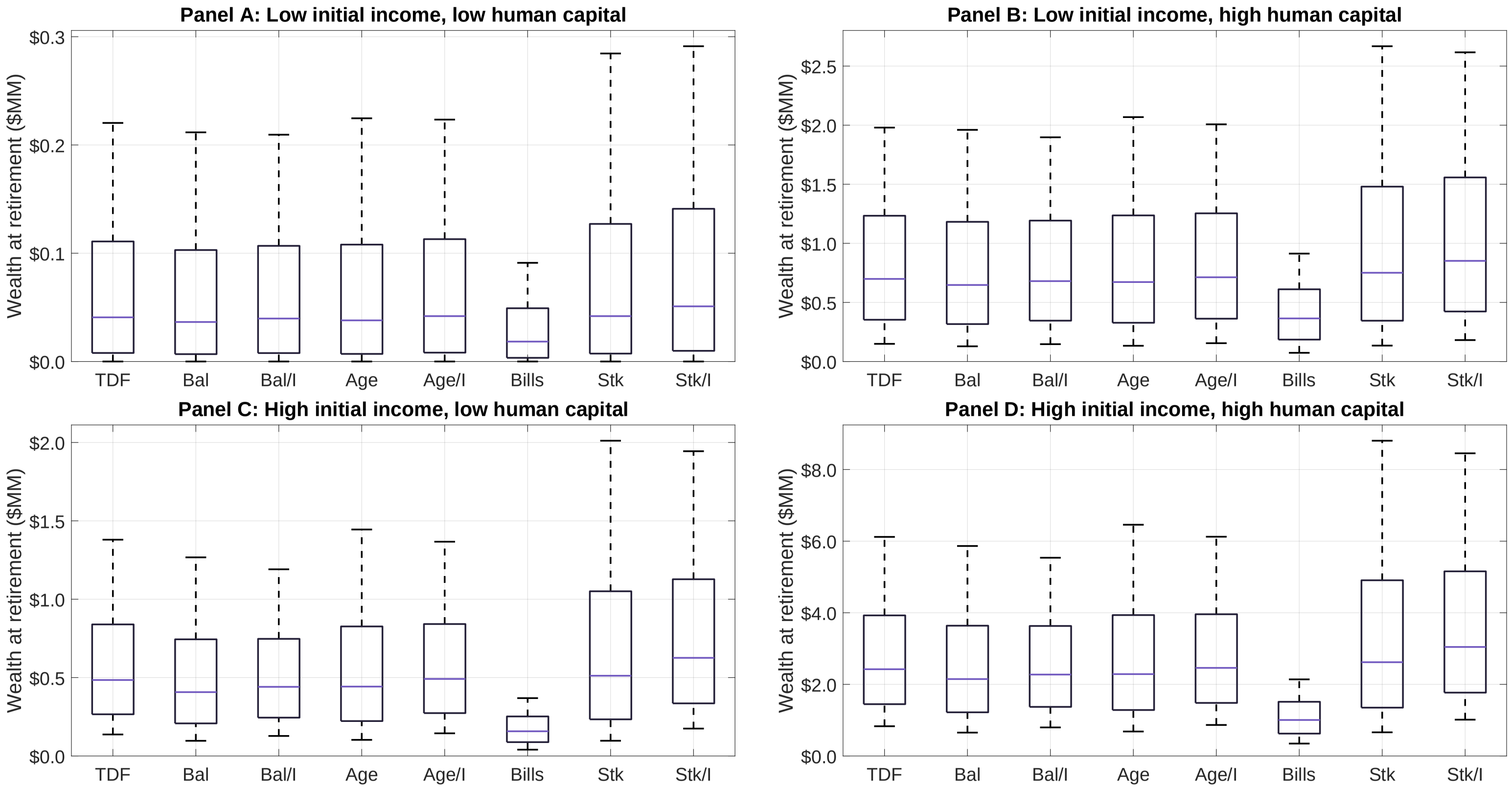


Figure B.6. Wealth at retirement by investor type. The figure summarizes the distribution of real wealth at retirement (in millions of 2022 USD) across 1,000,000 bootstrap simulations for households adopting various asset allocation strategies. Each panel of the figure corresponds to specific values for initial income (z_0^i) and human capital parameters (α^i, β^i). In each box-and-whiskers plot, the middle line corresponds to the median, the box covers the interquartile range, and the whiskers cover the 10th through 90th percentiles. Household income in the pre-retirement period is stochastic and follows the process estimated by Guvenen, Karahan, Ozkan, and Song (2021). The household's savings rate in the pre-retirement period is 10%. Household income in the post-retirement period is the sum of Social Security income and a constant real withdrawal of 4% of the household's investment account value at retirement (as long as the account has not been depleted). The household faces uncertainty over labor income, investment returns, and longevity.

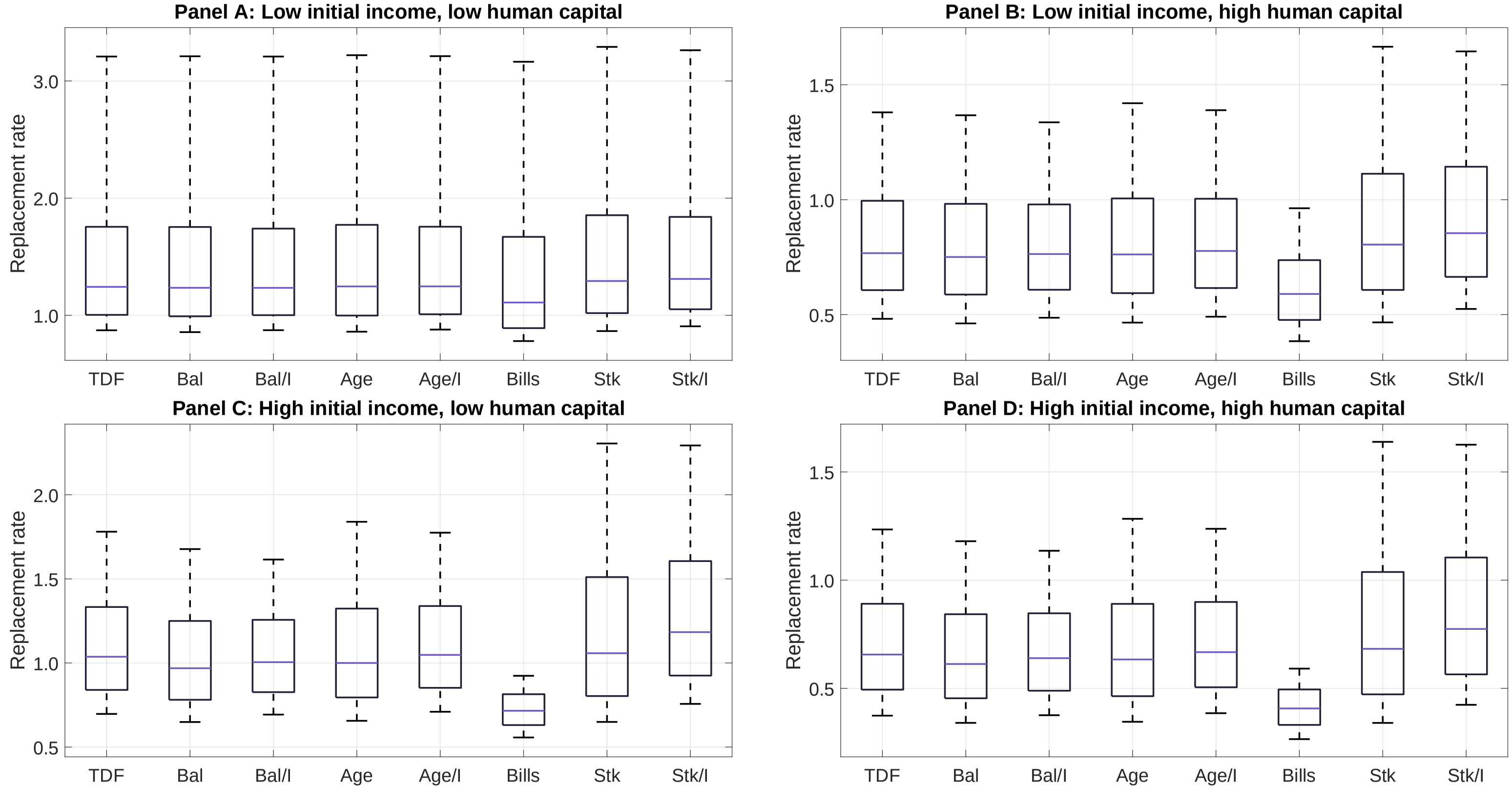


Figure B.7. Income replacement rates by investor type. The figure summarizes the distribution of the real income replacement rate across 1,000,000 bootstrap simulations for households adopting various asset allocation strategies. Each panel of the figure corresponds to specific values for initial income (z_0^i) and human capital parameters (α^i, β^i). In each box-and-whiskers plot, the middle line corresponds to the median, the box covers the interquartile range, and the whiskers cover the 10th through 90th percentiles. Household income in the pre-retirement period is stochastic and follows the process estimated by Guvenen, Karahan, Ozkan, and Song (2021). The household's savings rate in the pre-retirement period is 10%. Household income in the post-retirement period is the sum of Social Security income and a constant real withdrawal of 4% of the household's investment account value at retirement (as long as the account has not been depleted). The household faces uncertainty over labor income, investment returns, and longevity.

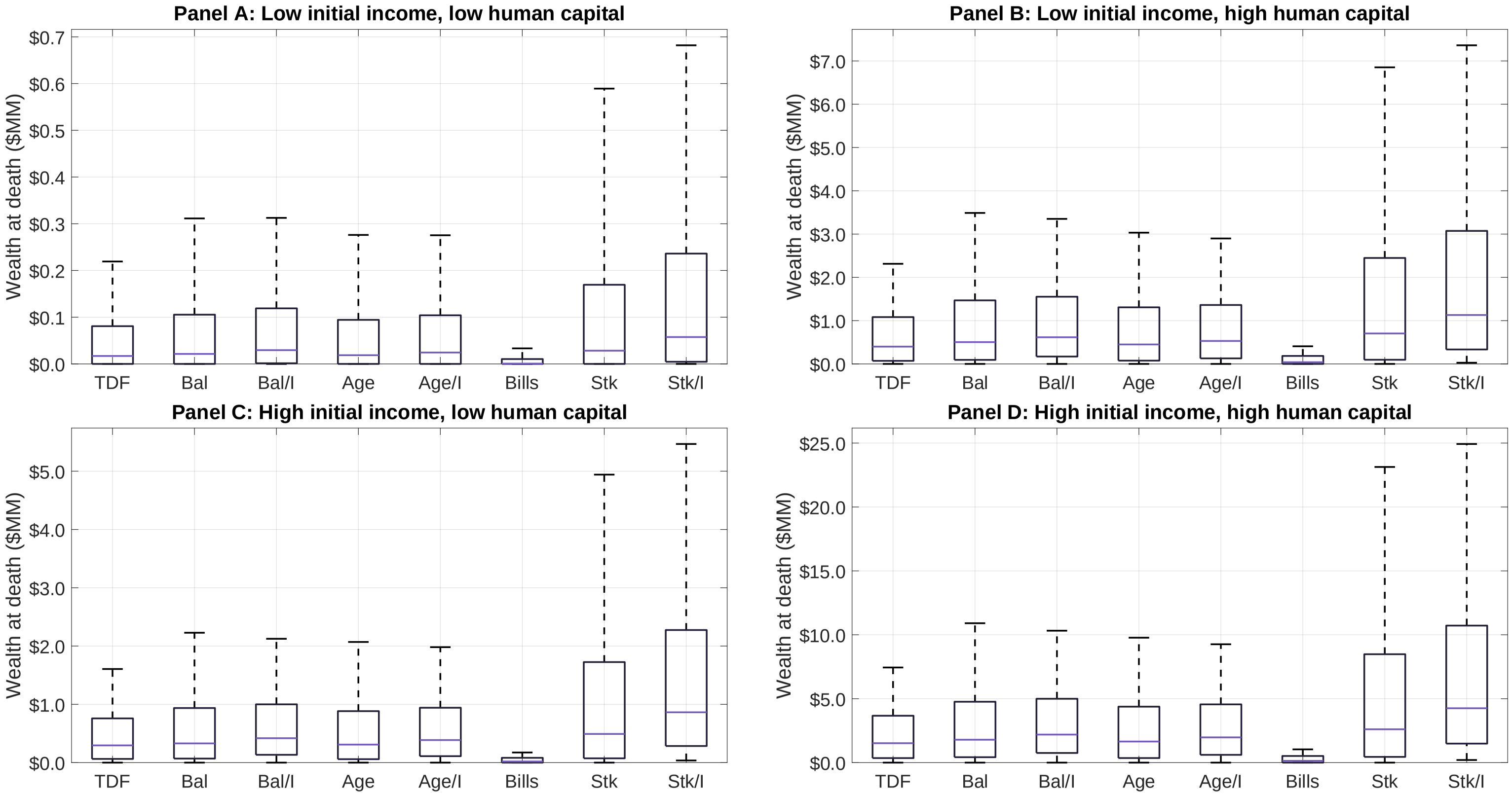


FIGURE B.8. WEALTH AT DEATH BY INVESTOR TYPE. The figure summarizes the distribution of real wealth at death (in millions of 2022 USD) across 1,000,000 bootstrap simulations for households adopting various asset allocation strategies. Each panel of the figure corresponds to specific values for initial income (z_0^i) and human capital parameters (α^i, β^i). In each box-and-whiskers plot, the middle line corresponds to the median, the box covers the interquartile range, and the whiskers cover the 10th through 90th percentiles. Household income in the pre-retirement period is stochastic and follows the process estimated by Guvenen, Karahan, Ozkan, and Song (2021). The household's savings rate in the pre-retirement period is 10%. Household income in the post-retirement period is the sum of Social Security income and a constant real withdrawal of 4% of the household's investment account value at retirement (as long as the account has not been depleted). The household faces uncertainty over labor income, investment returns, and longevity.

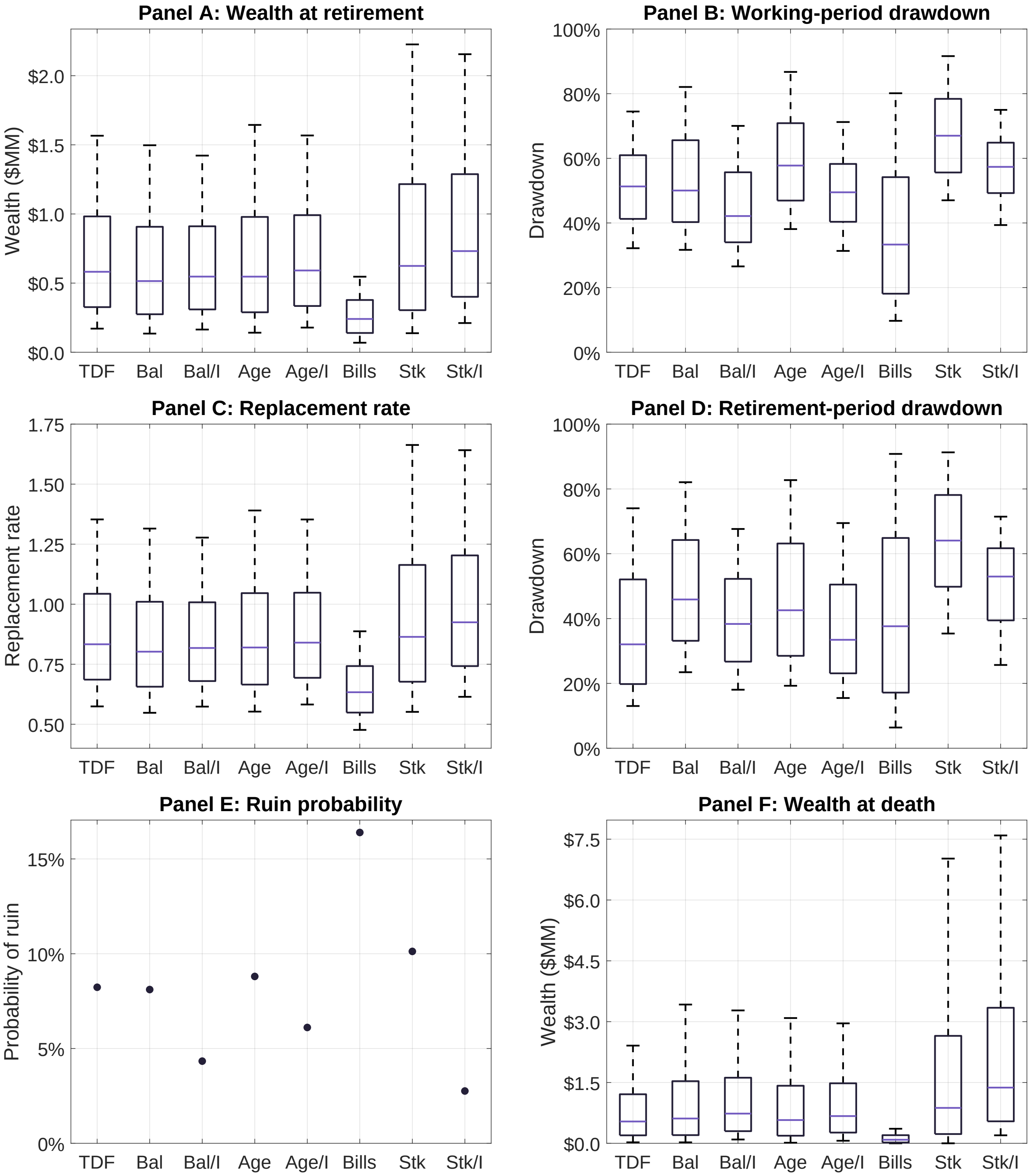


Figure B.9. Measures of investment performance: 3% withdrawal rule. The figure summarizes the distribution of real wealth at retirement (Panel A), the distribution of the working-period drawdown (Panel B), the distribution of the real income replacement rate (Panel C), the distribution of the retirement-period drawdown (Panel D), the probability of financial ruin (Panel E), and the distribution of real wealth at death (Panel F) across 1,000,000 bootstrap simulations for households adopting various asset allocation strategies. In each box-and-whiskers plot, the middle line corresponds to the median, the box covers the interquartile range, and the whiskers cover the 10th through 90th percentiles. Household income in the post-retirement period is the sum of Social Security income and a constant real withdrawal of 3% of the household's investment account value at retirement (as long as the account has not been depleted).

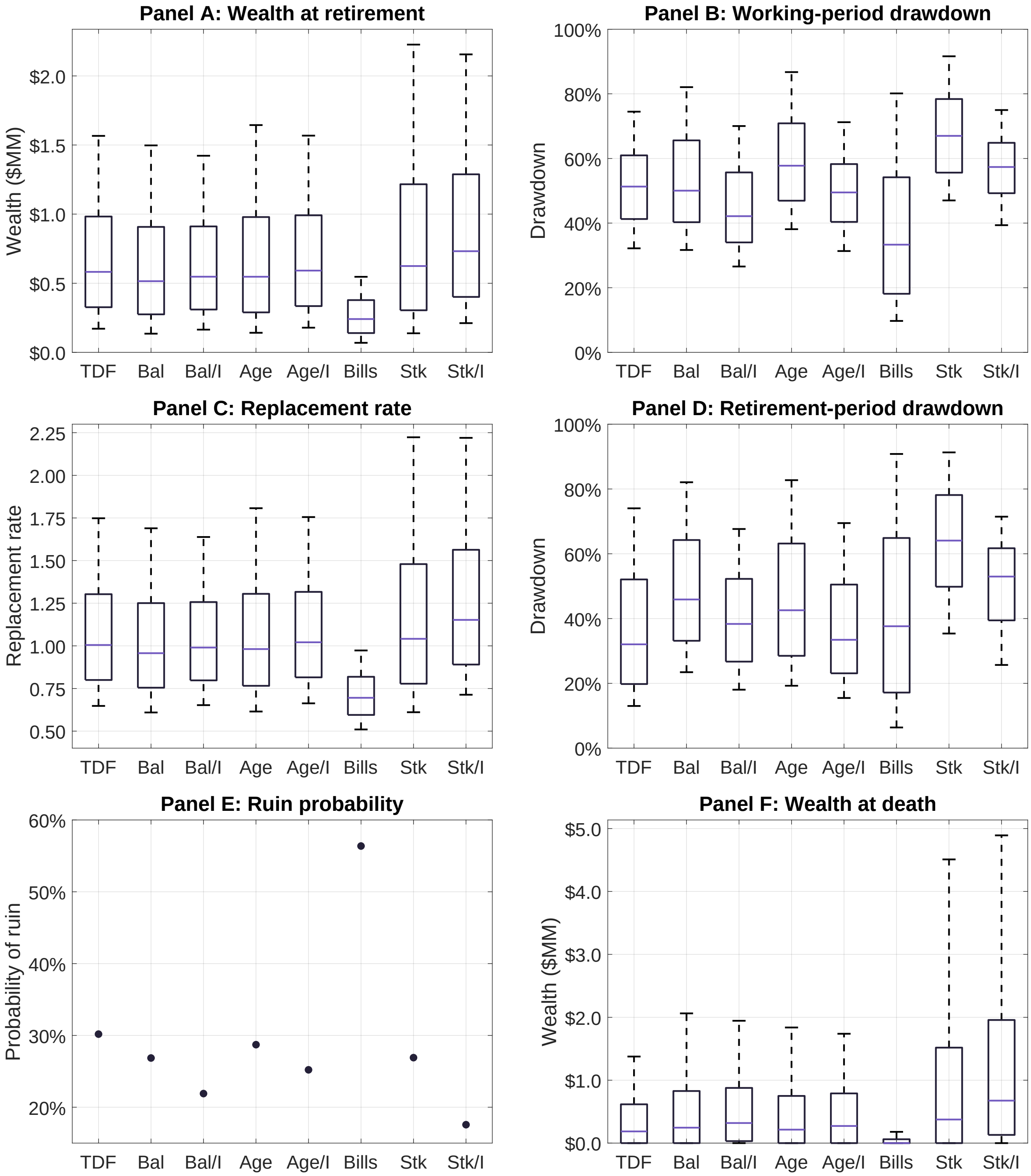


Figure B.10. Measures of investment performance: 5% withdrawal rule. The figure summarizes the distribution of real wealth at retirement (Panel A), the distribution of the working-period drawdown (Panel B), the distribution of the real income replacement rate (Panel C), the distribution of the retirement-period drawdown (Panel D), the probability of financial ruin (Panel E), and the distribution of real wealth at death (Panel F) across 1,000,000 bootstrap simulations for households adopting various asset allocation strategies. In each box-and-whiskers plot, the middle line corresponds to the median, the box covers the interquartile range, and the whiskers cover the 10th through 90th percentiles. Household income in the post-retirement period is the sum of Social Security income and a constant real withdrawal of 5% of the household's investment account value at retirement (as long as the account has not been depleted).

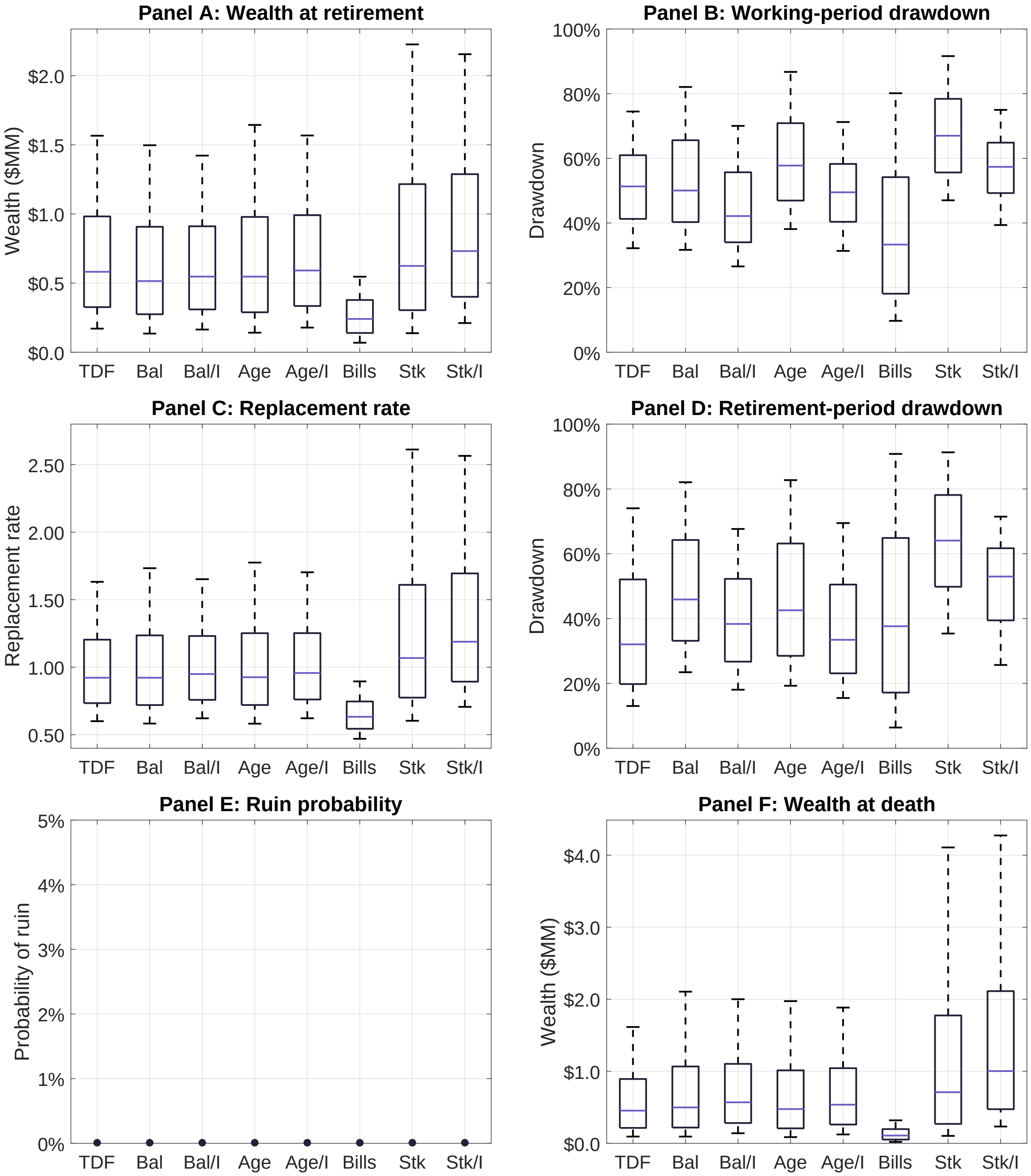


Figure B.11. Measures of investment performance: 4% of current investment account value withdrawal rule. The figure summarizes the distribution of real wealth at retirement (Panel A), the distribution of the working-period drawdown (Panel B), the distribution of the real income replacement rate (Panel C), the distribution of the retirement-period drawdown (Panel D), the probability of financial ruin (Panel E), and the distribution of real wealth at death (Panel F) across 1,000,000 bootstrap simulations for households adopting various asset allocation strategies. In each box-and-whiskers plot, the middle line corresponds to the median, the box covers the interquartile range, and the whiskers cover the 10th through 90th percentiles. Household income in the post-retirement period is the sum of Social Security income and a real withdrawal of 4% (annualized) of the household's investment account value at the beginning of the corresponding month.

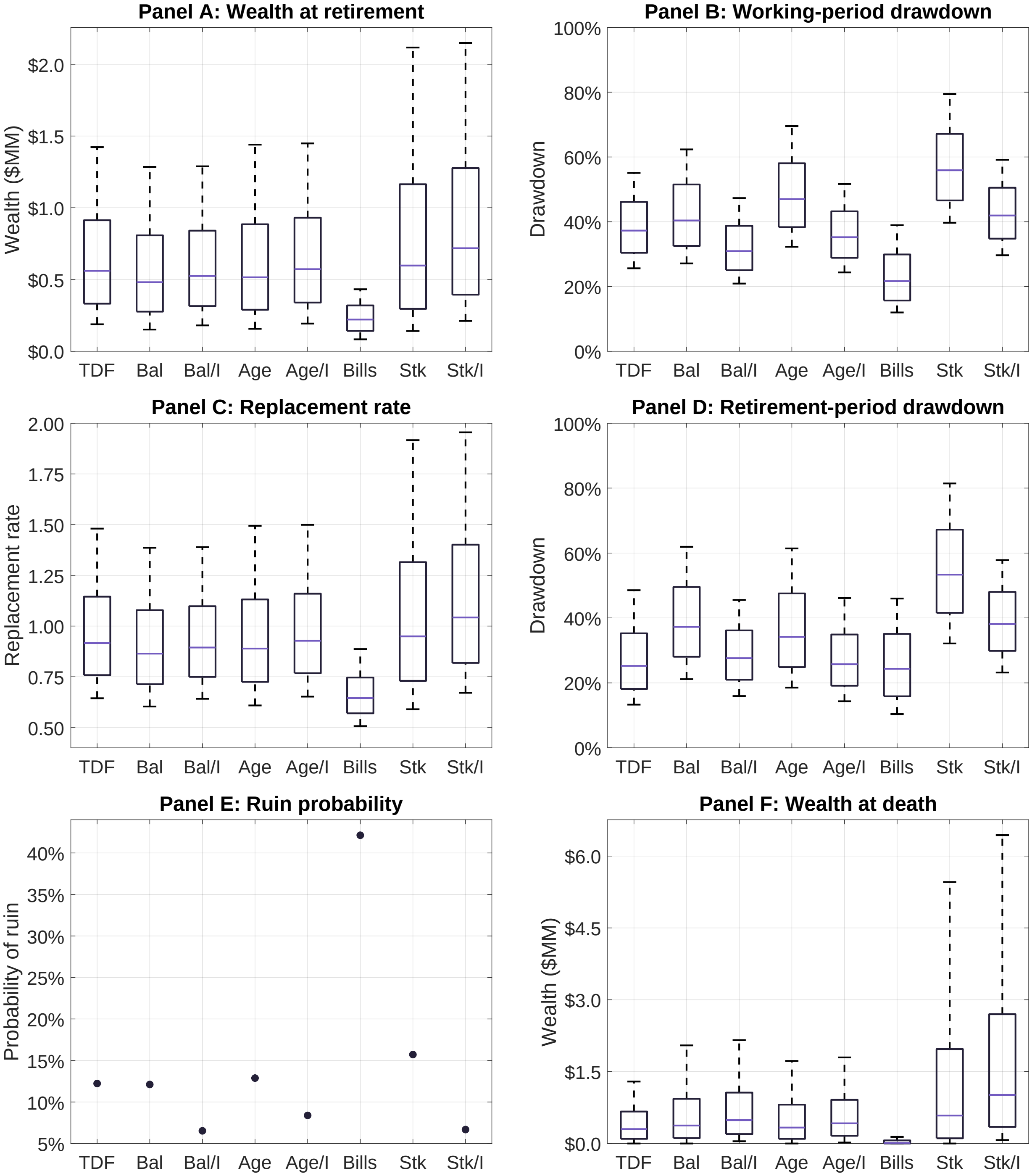


Figure B.12. Measures of investment performance: Developed country sample and IID bootstrap. The figure summarizes the distribution of real wealth at retirement (Panel A), the distribution of the working-period drawdown (Panel B), the distribution of the real income replacement rate (Panel C), the distribution of the retirement-period drawdown (Panel D), the probability of financial ruin (Panel E), and the distribution of real wealth at death (Panel F) across 1,000,000 bootstrap simulations for households adopting various asset allocation strategies. The underlying data sample for each simulation is the pooled sample of developed countries, and the simulations use an IID bootstrap sampling approach. In each box-and-whiskers plot, the middle line corresponds to the median, the box covers the interquartile range, and the whiskers cover the 10th through 90th percentiles.

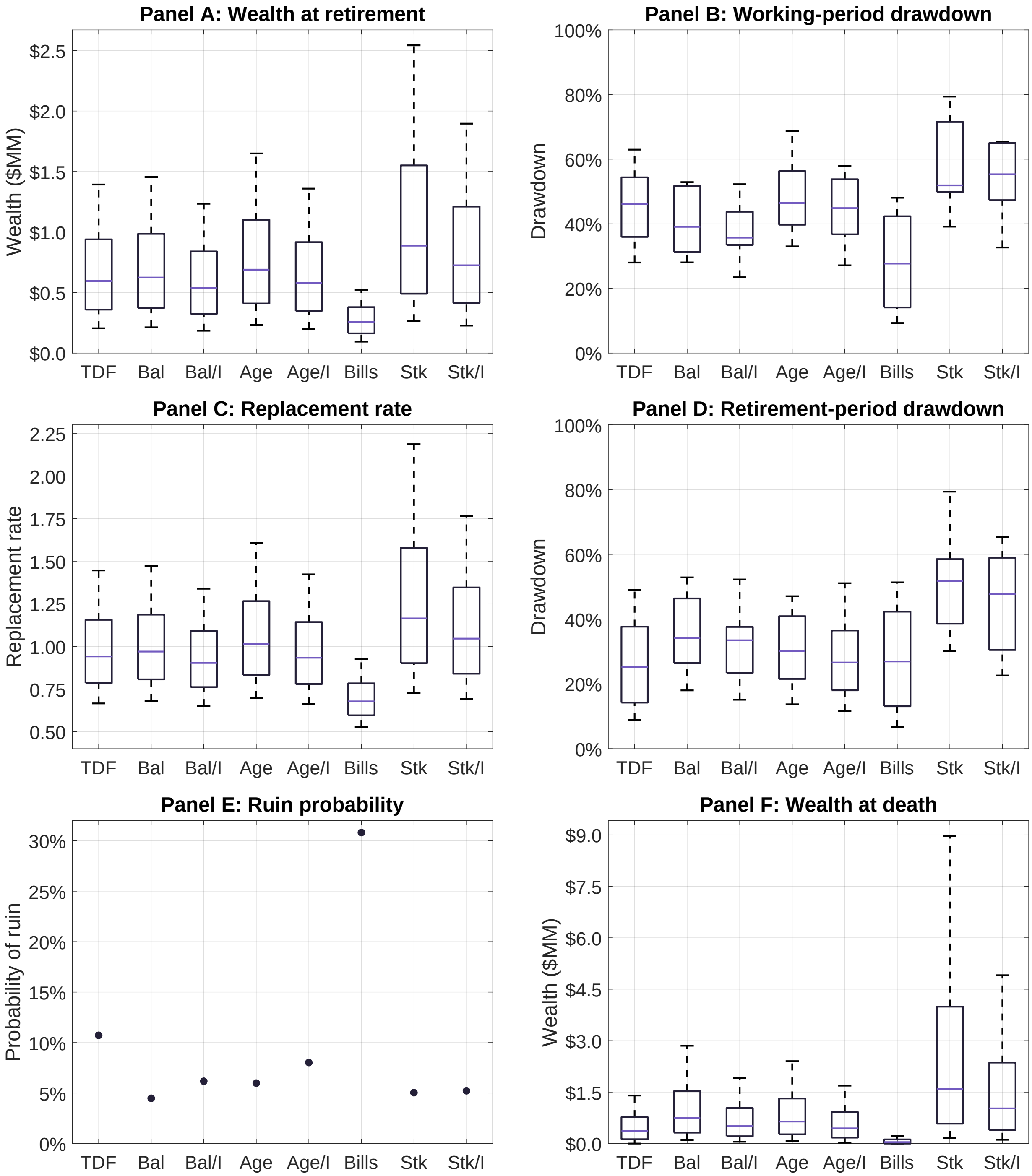


Figure B.13. Measures of investment performance: US sample and block bootstrap. The figure summarizes the distribution of real wealth at retirement (Panel A), the distribution of the working-period drawdown (Panel B), the distribution of the real income replacement rate (Panel C), the distribution of the retirement-period drawdown (Panel D), the probability of financial ruin (Panel E), and the distribution of real wealth at death (Panel F) across 1,000,000 bootstrap simulations for households adopting various asset allocation strategies. The underlying data sample for each simulation is US sample, and the simulations use a block bootstrap sampling approach with an average block length of 120 months. In each box-and-whiskers plot, the middle line corresponds to the median, the box covers the interquartile range, and the whiskers cover the 10th through 90th percentiles.

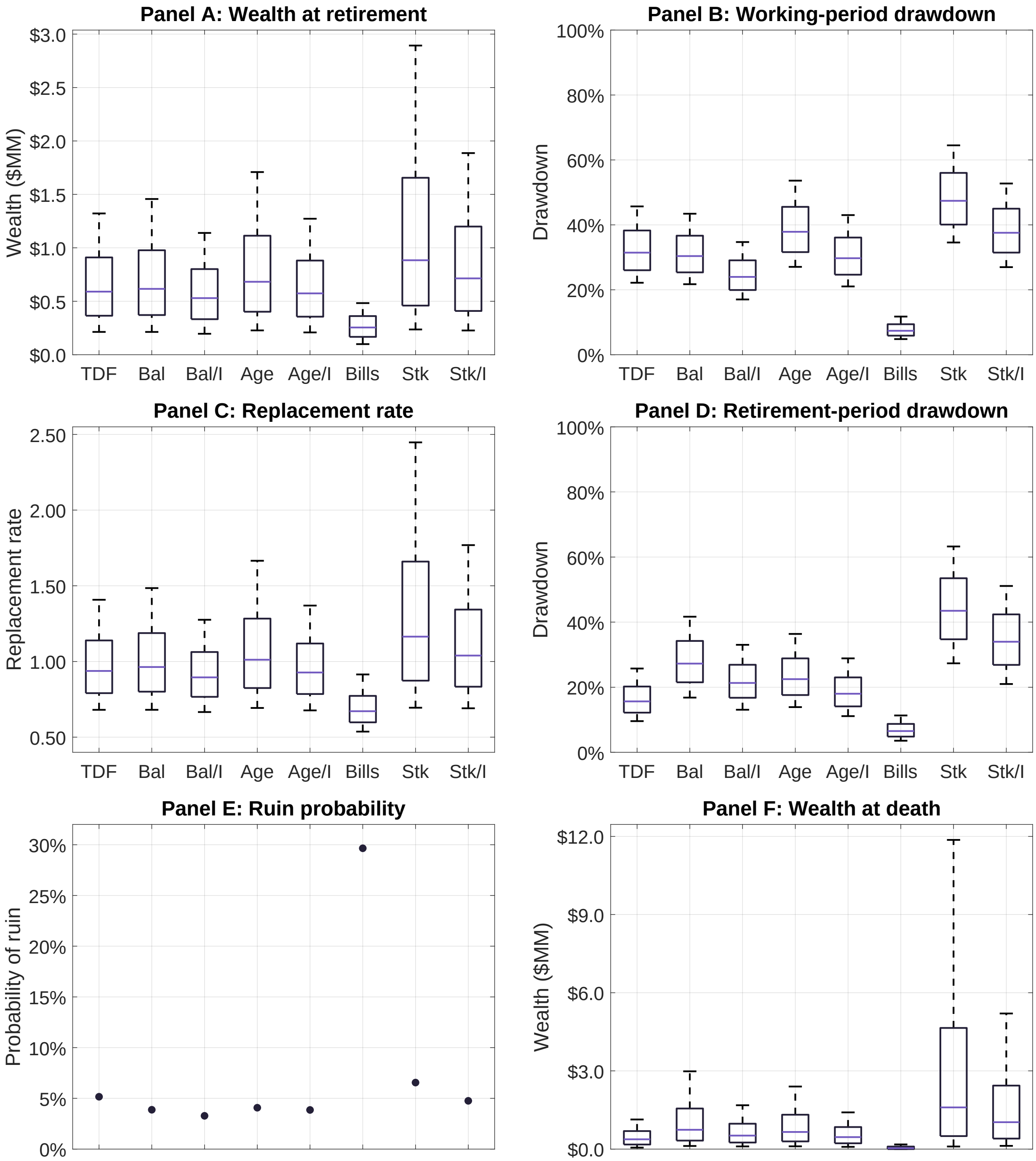


Figure B.14. Measures of investment performance: US sample and IID bootstrap. TThe figure summarizes the distribution of real wealth at retirement (Panel A), the distribution of the working-period drawdown (Panel B), the distribution of the real income replacement rate (Panel C), the distribution of the retirement-period drawdown (Panel D), the probability of financial ruin (Panel E), and the distribution of real wealth at death (Panel F) across 1,000,000 bootstrap simulations for households adopting various asset allocation strategies. The underlying data sample for each simulation is the US sample, and the simulations use an IID bootstrap sampling approach. In each box-and-whiskers plot, the middle line corresponds to the median, the box covers the interquartile range, and the whiskers cover the 10th through 90th percentiles.

References

Guvenen, Fatih, Fatih Karahan, Serdar Ozkan, and Jae Song, 2021, What do data on millions of U.S. workers reveal about lifecycle earnings dynamics?, *Econometrica* 89, 2303–2339.