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On the Asset Allocation of a Default Pension Fund

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ABSTRACT

We characterize the optimal default fund in a defined contribution (DC) pension plan. Using detailed data on individuals' holdings inside and outside the pension system, we find substantial heterogeneity within and between passive and active investors in terms of labor income, financial wealth, and stock market participation. We build a life-cycle consumption-savings model, with a DC pension account and an opt-out/default choice, that produces realistic investor heterogeneity. Relative to a common age-based allocation, implementing the optimal default asset allocation implies a welfare gain of 1.5% during retirement. Much of the gain is attainable with a simple rule of thumb.

THE WORLDWIDE SHIFT FROM DEFINED benefit (DB) to defined contribution (DC) pension plans challenges pension investors, who have been given greater responsibility to choose their contribution rates and manage their asset allocations. Many investors seem uninterested, display inertia (Madrian and Shea (2001)), or lack financial literacy (Lusardi and Mitchell (2014)), ending up in the default option. Consequently, the design of the default option in a pension plan may be a powerful tool for improving investment outcomes.[1]

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[1] Prior studies examine the design of the enrollment features (Carroll et al. (2009)), contribution rates (Madrian and Shea (2001), Choi et al. (2003)), choice menus (Cronqvist and Thaler (2004)), and equity exposures of pension plans (Benartzi and Thaler (2001), Huberman and Jiang (2006)). Benartzi and Thaler (2007) review heuristics and biases in retirement savings behavior. More recently, Chetty et al. (2014) document inertia among pension investors with respect to their con-

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This paper studies one important aspect of the design of the default pension fund—the optimal asset allocation. The asset allocation is particularly well suited to the design of an individualized default fund as the optimal allocation decision requires knowledge of asset classes and financial literacy, while knowledge of the optimal contribution rate may be known only by the individual (Carroll et al. (2009), Choi, Laibson, and Madrian (2010)). We make both an empirical and a theoretical contribution to this literature. We begin by constructing a data set of Swedish investors' detailed asset holdings inside and outside the pension system.[2] We find that remaining in the default fund, or not changing funds for a long time after an initial opt-out decision, is a strong indicator of having no equity exposure outside the pension system. These passive investors' stock market participation rate outside the pension system is 16 percentage points lower than that of active investors, with one-third of the difference not explained by observable characteristics such as labor income, financial wealth, and education. Overall, passive investors can be characterized as less sophisticated. Moreover, we find considerable heterogeneity among passive investors. Passive investors participating in the stock market have financial wealth equal to 1.4 years of labor income, while passive investors not participating in the stock market have financial wealth equal to only five months of labor income. Similarly, participating passive investors have 4.3 times as much financial wealth as nonparticipating passive investors. These basic facts call into question the ability of a one-size-fits-all default fund to meet all passive investors' needs.

Motivated by these findings, we develop a model to study the optimal asset allocation of passive investors' default fund. Our model belongs to the class of life-cycle portfolio choice models with risky labor income (see, for example, Viceira (2001), Cocco, Gomes, and Maenhout (2005), Gomes and Michaelides (2005)), meaning that it generates cross-sectional heterogeneity in income and wealth. We extend the model to include a pension system with a DC pension account, so that illiquid savings inside the pension system coexist with liquid savings outside it. The decision of whether to be active or passive in the DC pension account and the decision of whether to participate in the stock market outside the pension system are endogenous but subject to costs. We justify a dispersion in costs with heterogeneity in financial literacy and financial sophistication (e.g., experience making investment decisions and various costs associated with investing). While endogenous stock market participation is standard in the literature, our model is the first to endogenously determine the passive pension investors who remain in the default fund.

tribution rates, Poterba (2014) discuss the savings rates required to obtain warranted replacement rates, and Sialm, Starks, and Zhang (2015) argue that sponsors of DC plans should adjust plan options to overcome investor inertia.

[2] Calvet, Campbell, and Sodini (2007, 2009) use data on asset holdings outside the pension system. To the best of our knowledge, we are the first to combine these register-based data with information about savings inside the pension system. Bergstresser and Poterba (2004) and Christelis, Georgarakos, and Haliassos (2011) use survey data when studying equity exposure and location choice between taxable and tax-deferred accounts.

The model provides a normative suggestion regarding the asset allocation in the default fund. We find substantial cross-sectional heterogeneity in the optimal DC equity share: the year before retirement, 10% of default investors have an optimal DC equity share of 39% or more, while 10% of default investors have an optimal DC equity share of 9% or less. We also find that the optimal DC equity share varies substantially with past stock market performance: from the perspective of a 25-year-old, there is a 10% probability that the optimal DC equity share will be 34% or more in the year before retirement, and a 10% probability that it will be 20% or less. The latter result implies that different birth cohorts' optimal DC equity share depends on realized returns during the different cohorts' working phase. Conceptually, the optimal equity exposure in an individual's DC account depends on the account balance relative to both the individual's financial wealth outside the pension system and the present value of the individual's future labor income (Merton (1971)). This means that the DC account balance is a useful guide for active rebalancing. For example, if the account balance is low (high) due to poor (good) past equity returns, more (less) equity risk can be assumed. The same reasoning applies to idiosyncratic labor income shocks.

That passive and active investors are endogenously determined in the model is important. As in Carroll et al. (2009), the composition of passive investors endogenously adapts to changes in the default fund design. In this paper, the design feature of interest is the asset allocation. We examine how the share of passive investors changes as the degree to which the default is customized to individual circumstances increases. Starting from a common age-based investing rule (i.e., the percentage allocated to equity is equal to 100 minus one's age), we find that a simple rule of thumb conditioned on the investor's age, DC account balance, and stock market participation status reduces the share of active investors (who opt out) by 16.6 percentage points. Moreover, we find that this rule can be robustly estimated across different samples of default investors. This suggests that the rule is flexible enough to accommodate default investors who come from different institutional settings and initial designs.

In terms of welfare gains, moving from age-based investing to full customization of the default fund implies individual gains in certainty-equivalent consumption on the range of 0.9% to 2.9% during the retirement phase, with an average gain of 1.5%. Much of the average gain, 0.9%, is attainable if the proposed rule of thumb is implemented. To put the gain from the rule of thumb in perspective, we find that shifting from the best age-based asset allocation rule to the rule of thumb implies a gain of 0.6%. In contrast, shifting from the best constant asset allocation to the best age-based asset allocation implies a gain of 0.4%. Thus, implementing the rule of thumb can add as much value as implementing age-based glide paths for the equity share or introducing target dates. Another noteworthy observation is that, in our partial equilibrium setting, such a change to the default fund's asset allocation is Pareto-improving: from an ex ante perspective, there are only winners and no losers.

Importantly, our main results are robust to several modifications of the model. In particular, the welfare gain, the fraction of it attained using the rule of thumb, and the change in the fraction of investors who opt out hold if investors' portfolio choices outside the pension system are subject to frictions or investment mistakes (Choi, Laibson, and Madrian (2009), Card and Ransom (2011), Chetty et al. (2014), Campbell (2016)), if the equity risk premium is low, if equity returns are skewed to the left, if the correlation between labor income growth and equity returns is high, or if investors can withdraw wealth tied up in real estate during retirement.

Our work relates to that of Gomes, Michaelides, and Polkovnichenko (2009), Campanale, Fugazza, and Gomes (2014), and Dammon, Spatt, and Zhang (2004). Gomes, Michaelides, and Polkovnichenko (2009) study the effects of tax-deferred retirement accounts and find the largest effects on savings rates relative to a nontax environment for investors with high savings rates. Campanale, Fugazza, and Gomes (2014) investigate how stock market illiquidity affects a portfolio choice model's ability to replicate the distribution of stock holdings over the life cycle and the wealth distribution. Dammon, Spatt, and Zhang (2004) study the location decision for stocks and bonds in liquid taxable and illiquid tax-deferrable accounts.

Our work also relates to that of Lucas and Zeldes (2009), who examine the investment decisions of pension plans in the aggregate, and Abel (2001), who considers the aggregate implications of an asset allocation change to a fully funded DC social security system when some workers do not participate in the stock market. Our model, however, considers individual outcomes beyond aggregate ones at the pension plan level. In this sense, Shiller's (2006) evaluation of life-cycle personal accounts for social security is closer to our study. Our focus on investor heterogeneity complements the work of Poterba et al. (2007), who simulate individuals' pension benefits in DB and DC plans and report distributions across individuals.

The paper proceeds as follows. Section I provides an overview of the Swedish pension system. Section II describes our data. Section III empirically analyzes individuals' portfolio choices inside and outside the pension system and how they are related. Section IV presents our life-cycle model and its calibration. Section V analyzes the optimal design of the default pension fund as well as gradual customization, and presents results of several robustness tests. Finally, Section VI concludes. An Internet Appendix provides supporting details.[3]

I. The Swedish Pension System

The Swedish pension system rests on three pillars: public pensions, occupational pensions, and private savings. Below, we describe the public and occupational pensions.

[3] The Internet Appendix may be found in the online version of this article.

The public pension system was reformed in 2000.[4,5] It has two major components, namely, the income-based pension and the premium pension. A means-tested benefit provides a minimum guaranteed pension.

The contribution to the income-based pension is 16% of an individual's capped income (in 2016 the cap was SEK 444,750, or approximately USD 53,300).[6] The return on the contribution equals the aggregate labor income growth rate as measured by an official "income index." Effectively, the return on the income-based pension is similar to that of a real bond. The income-based pension is notional in that it is not reserved for the individual but is instead used to fund current pension payments as in a traditional pay-as-you-go system. The notional income-based pension is also DC, but to avoid confusion we refer to it as the notional pension.

The contribution to the premium pension is 2.5% of an individual's income (capped as above). Unlike the income-based pension, the premium pension is a fully funded DC account used to finance the individual's future pension. Individuals can choose to actively allocate their contributions to up to five mutual funds from a menu of several hundred. The premium pension makes it possible for individuals to gain equity exposure. Indeed, most of the investments in the system have been in equity funds (see, for example, Dahlquist, Martinez, and Söderlind (2017)). A government agency manages a default fund for individuals who are passive and do not make an investment choice. Up to 2010, the default fund invested mainly in stocks but also in bonds and alternatives. In 2010, the default fund became a life-cycle fund. At retirement, the savings in the income-based pension and the premium pension are transformed into actuarially fair lifelong annuities.

In addition to public pensions, approximately 90% of the Swedish workforce is entitled to occupational pensions. Agreements between labor unions and employer organizations are broad and inclusive and have gradually been harmonized across educational and occupational groups. For individuals born after 1979, the rules are fairly homogeneous, regardless of education and occupation. The contribution is 4.5% of an individual's income up to the cap in the public pension system and greater for the part of the income that exceeds that cap, to compensate for the cap in the public pension and to achieve a similar replacement rate. These contributions go into a designated individual DC account. While the occupational pension is somewhat more complex and tailored to specific needs, it shares many features with the premium pension. Specifically, it is an individual DC account, there is a menu of mutual funds to choose from, and the plan sponsor chooses the default fund.

[4] Carlsson, Erlandzon, and Gustavsson (2008) analyze this reform using a life-cycle portfolio choice model.

[5] Individuals born between 1938 and 1954 are enrolled in a mix of the old and new pension systems, while individuals born after 1954 are enrolled entirely in the new system.

[6] At the beginning of 2016, the SEK/USD exchange rate was 8.35. During our sample period, the exchange rate fluctuated between 6 and 10 SEK per USD. We often report numbers from 2007, when the exchange rate at the end of the year was 6.47. We henceforth report numbers in SEK.

Next we discuss our data on individuals' savings inside and outside the pension system.

II. Data

We tailor a registry-based data set to our needs. This data set's foundation comes from a representative panel data set for Sweden, referred to as Longitudinal Individual Data (LINDA). LINDA covers more than 300,000 households and is compiled by Statistics Sweden. We use eight waves between 2000 and 2007 and consider socioeconomic information such as age, education, and labor income. Our sample period is determined by the launch of the new pension system in 2000 and by the availability of detailed financial wealth data (described below) up to 2007. The Internet Appendix (Section I) contains further information on LINDA. We match LINDA with data from two additional sources.

We first add data from the Swedish Tax Agency (through Statistics Sweden) covering individual nonpension financial wealth. This is a registry-based source of financial holdings outside the public pension system. Specifically, the tax records allow us to compute the value of all bonds, stocks, and mutual funds that an individual holds at each year-end. There are three exceptions to these detailed tax reports. First, for holdings of financial assets within private pension accounts, we observe additions and withdrawals only since 1991. Second, bank accounts with small balances are missing. To match the aggregate, these missing values are imputed. Third, for the so-called capital insurance accounts, we observe the account balances but not the detailed holdings.[7] The tax records also combine information on real estate taxes, which allows us to accurately measure the value of owner-occupied single-family houses and second homes. Apartment values are also available, though they are less accurately measured. Finally, we observe total debt (e.g., mortgages and student loans).

We also add pension savings data from the Swedish Pensions Agency. These data contain information on individuals' entry into the pension system and on their mutual fund holdings in their premium pension accounts at each year-end. Unfortunately, it is impossible to match these data with occupational pension accounts because these accounts are administered by private entities. Moreover, individuals' holdings in occupational pension plans are not covered by the tax-based data set described above. However, we know the typical contribution rates in occupational pension plans and the typical allocations of these plans to equities and bonds. In our model, we assume that the typical contribution rates and allocations in occupational pension plans apply to all enrolled individuals.

Previous studies use the tax-based holdings information and records from the Swedish Pensions Agency separately. For instance, Calvet, Campbell, and

[7] Capital insurance accounts are savings vehicles that are exempt from regular capital gains and dividend income taxes, and instead taxed at a flat rate on the account balance. According to Calvet, Campbell, and Sodini (2007), these accounts amounted to 16% of aggregate financial wealth in 2002.

Sodini (2007, 2009), Vestman (2017), and Koijen, Van Nieuwerburgh, and Vestman (2015) use nonpension financial wealth to examine questions related to investors' diversification, portfolio rebalancing, housing and stock market participation, and consumption expenses, while Dahlquist, Martinez, and Söderlind (2017) use information from the Swedish Pensions Agency to analyze the activity and performance of pension investors. To the best of our knowledge, we are the first to combine comprehensive, high-quality panel data on individuals' investments inside and outside the pension system.

III. Empirical Analysis

A. Sample Restrictions

We begin with all individuals in the 2007 wave of LINDA and match them with Swedish Pensions Agency records of DC account holdings at every year-end between 2000 and 2007. This leads to a sample of 430,216 individuals covered in both data sets. We next impose four sample restrictions. We first exclude individuals for whom we lack portfolio information at the end of each year since they entered the premium pension system. Second, to better match the model to data, we exclude the richest percentile in terms of net worth. Third, we exclude individuals below age 25 years as they do not fully qualify for occupational pension plans. Finally, we exclude individuals for whom we lack educational information. This last restriction applies mainly to recent immigrants and the very old. Our final sample comprises 301,632 individuals.

B. Passive and Active Pension Investors

We classify all individual investors as passive or active based on their DC account activity between 2000 and 2007. Passive investors are investors who have had their premium pension in the default fund since entering the pension system or who opted out of the default fund when entering the pension system but have never changed their allocations.

The default investors have clearly been passive. Our classification of initially active investors as passive is based on three observations. First, at the time of the new system launch, investors were strongly encouraged to actively choose a portfolio of one's own. This was done via massive advertising campaigns from the government and money management firms (see Cronqvist and Thaler (2004), who characterized the plan launch as "pro choice"). That many individuals who opted out never made subsequent allocation changes suggests that they would have been in the default fund if not so strongly encouraged to opt out. Second, Dahlquist, Martinez, and Söderlind (2017) document that initially active investors have had on average worse returns than active and default investors, which refutes the idea that their passivity is due to complacency. Finally, our classification is consistent with the substantial increase in default investors in the years after the launch. For example, among 25-year-old individuals, the fraction of new investors who stayed in the default increased from 27% in 2000 to 66% in 2001, after which it increased steadily to 92% in 2007.

In contrast to passive investors, active investors opted out of the default fund and have made at least one change to their allocations. Note that our activity-based classification relies on the panel dimension of the data. Previous analyses of the choice between taxable and tax-deferred accounts rely on cross-sectional data (see, for example, Christelis, Georgarakos, and Haliassos (2011)).

C. Summary Statistics

Table I reports averages of the key variables in 2007. The first column reports the values for all investors and the remaining two columns report the values for passive and active investors separately. Passive investors account for 60.5% of investors while active investors account for 39.5%. Of the passive investors, 51.8% are default investors and the remaining 48.2% opted out of the default fund when entering the pension system but have never changed their allocations.

The average investor is 47 years old, with no substantial difference in age between passive and active investors. The average labor income of a passive investor is SEK 224,526, or only 79% of the average labor income of active investors. This ratio remains fairly stable over the life cycle, and thus the difference in labor income between passive and active investors is not attributable to age differences, but rather is likely an artifact of other differences (e.g., educational and industry differences, as discussed below). Similarly, the financial wealth (i.e., liquid savings not tied to pension accounts) of the average passive investor is only 74% of that of the average active investor. This means that the pension savings, which are proportional to labor income absent differences in returns, are relatively more important to passive investors.

The table also reports stock market exposure outside the pension system. We define stock market participation as direct investments in stocks or investments in equity mutual funds. The stock market participation rate is 45.5% for passive investors and 61.9% for active investors, that is, passive investors have a 16.4 percentage-point-lower stock market participation rate than active investors. The lower participation of passive investors also shows up in equity shares, with the average equity share equal to 19.6% for passive investors and 29.0% for active investors. However, conditioning on stock market participation, passive and active investors have similar equity shares (43.2% and 46.9%, respectively).

There are also large differences in real estate ownership. The ownership rate among passive investors is 65.2%, which is much lower than the 79.3% among active investors. The differences in financial and real estate wealth are also reflected in net worth, which is equal to real estate wealth plus financial wealth minus total liabilities. Average net worth among passive investors equals 79% of average net worth among active investors, which implies that the net worth-to-labor income ratio is similar for the two groups. Notably, net worth is almost

Table I

Variable Averages

The table presents averages of variables for all investors and investor categories in 2007. Numbers are reported in SEK. At the end of 2007, the SEK/USD exchange rate was 6.47. "Passive" refers to investors who are invested in the default fund or who opted out of the default fund when entering the pension system but have never changed their allocations. Of the passive investors, 94,496 (or 51.8%) are default investors. "Active" refers to investors who, after entering the pension system, made at least one change to their allocations. The number of investors is the number of investors in each category. The fraction of investors is the number of investors in each category relative to the total number of investors. Labor income is gross annual labor income. Financial wealth refers to financial wealth outside the pension system (i.e., bank accounts, direct bond and stock holdings, mutual funds) as well as balances in private pension accounts and capital insurance. The balance in private pension accounts is imputed by accumulating the net flows since 1991. We therefore assume a zero balance at the end of 1990. The participation dummy is assigned a value of one if the investor holds either stocks or equity funds outside the pension system. The conditional equity share corresponds to investors who participate in the stock market, where we assume that capital insurance and private pension accounts comprise 60% equities and 40% bonds. The unconditional equity share is the value-weighted equity share over all investors. The real estate dummy is assigned a value of one if the investor owns either a house or an apartment. Real estate wealth is the value of houses and apartments (not conditioning on owning real estate). Net worth is the sum of financial wealth and real estate wealth minus total debt (e.g., mortgages, credit card debt, and student loans). The loan-to-value ratio equals financial wealth plus real estate wealth minus net worth, which is then divided by real estate wealth; it equals 0.45 for both the passive and the active investor categories. The educational dummies are assigned a value of one for the investor's highest obtained education.

	All	Passive	Active
Investors			
Number of investors	301,632	182,487	119,145
Fraction of investors	1.000	0.605	0.395
State variables			
Age	46.8	46.6	47.0
Labor income	248,420	224,526	285,017
Financial wealth	248,039	217,846	294,284
Stock market exposure			
Participation dummy	0.520	0.455	0.619
Equity share (unconditional)	0.234	0.196	0.290
Equity share (conditional)	0.449	0.432	0.469
Real estate ownership and net worth			
Real estate dummy	0.708	0.652	0.793
Real estate wealth	893,784	817,972	1,009,899
Net worth	737,760	665,790	847,993
Educational dummies			
Elementary school	0.157	0.184	0.116
High school	0.544	0.539	0.551
College	0.288	0.267	0.320
PhD	0.011	0.010	0.013

three times as large as financial wealth in both groups, an observation that we elaborate on later.

Finally, passive and active investors also differ in education. Though the fraction of high school graduates is about the same (53.9% for passive investors and 55.1% for active investors), the fraction of investors with a college degree is five percentage points lower among passive investors than among active investors (26.7% versus 32.0%) and passive investors are much more likely than active investors to have finished only elementary school (18.4% versus 11.6%).

D. Activity and Stock Market Participation

We next turn to a more formal comparison of investment behavior inside and outside the pension system. Specifically, we study how activity inside the pension system relates to stock market participation outside the pension system. We begin by running two main regressions:

$$D(\text{Activity}_i = 1) = \alpha' X_i + \varepsilon_i^{\text{A}} \tag{1}$$

and

$$D(\text{Participation}_i = 1) = \beta' X_i + \varepsilon_i^{\text{P}}, \tag{2}$$

where $D(\text{Activity}_i = 1)$ is a dummy variable that takes a value of one if the individual is active inside the pension system, $D(\text{Participation}_i = 1)$ is a dummy variable that takes a value of one if the individual holds stocks directly or holds equity funds outside the pension system, X_i is a vector of individual characteristics, and ε_i^{A} and ε_i^{P} are error terms. As the classification of activity refers to the 2000 to 2007 period, we restrict attention to activity and participation at the end of 2007. We let the individual continuous characteristics enter linearly, and as an alternative we consider piecewise linear splines for them, as in, for example, Chetty, Sándor, and Szeidl (2017). The characteristics are chosen to be largely consistent with a structural life-cycle model of portfolio choice, similar to the model that we develop in the next section. In particular, the individual characteristics include age, labor income, and financial wealth, as well as a real estate dummy, educational dummies, geographical dummies, and industry dummies. All characteristics are measured at the end of 2007.

We next run the complementary regression

$$\hat{\varepsilon}_i^{\text{P}} = \gamma \hat{\varepsilon}_i^{\text{A}} + \varepsilon_i, \tag{3}$$

where $\hat{\varepsilon}_i^{\text{A}}$ and $\hat{\varepsilon}_i^{\text{P}}$ are the residuals from regressions (1) and (2), and ε_i is an error term. This residual regression helps us understand the commonality of endogenous activity inside the pension system and endogenous stock market participation outside the pension system, after controlling for the individual characteristics in X_i. We emphasize that we make no causal interpretation (i.e., that activity would cause participation)—the regression simply captures the correlation between activity and participation after controlling for age, labor income, financial wealth, etc.

Panel A in Table II reports the results of the main regressions, (1) and (2). (Note that in the regressions, age is scaled down by 100 and labor income and financial wealth are scaled down by 1,000,000.) Specifications (1)

Table II

Activity and Stock Market Participation

Panel A presents the results of regressions of activity and stock market participation on various variables. Specifications (1) and (2) regress an activity dummy (one if the investor is active in the pension system, zero otherwise) on the variables; Specifications (3) and (4) regress a participation dummy (one if the investor participates in the stock market, zero otherwise) on the variables. Specifications (1) and (3) use the state variables of a life-cycle portfolio choice model (i.e., age, labor income, and financial wealth) and a dummy for real estate ownership as regression variables. Age is scaled down by 100, and labor income and financial wealth are scaled down by 1,000,000. All specifications include educational, geographical, and industry dummy variables. Specifications (2) and (4) replace the linear specifications of age, labor income, and financial wealth with piecewise linear splines. For brevity, the coefficients of these variables are not presented in the table. Panel B presents the results of regressions of the residuals from the participation regressions (Specifications (3) and (4)) on the residuals from the activity regressions (Specifications (1) and (2)). The sample comprises investors in 2007. At the end of 2007, the SEK/USD exchange rate was 6.47. Standard errors, robust to conditional heteroskedasticity, are reported in parentheses.

	Activity dummy		Participation dummy	
	(1)	(2)	(3)	(4)
Panel A: Main Regressions				
Age	0.095	–	0.275	–
	(0.009)		(0.008)	
Labor income	0.146	–	0.109	–
	(0.005)		(0.004)	
Financial wealth	0.050	–	0.279	–
	(0.002)		(0.002)	
Real estate dummy	0.115	0.067	0.160	0.073
	(0.002)	(0.002)	(0.002)	(0.002)
Educational dummies	Yes	Yes	Yes	Yes
Geographical dummies	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes
Age/income/wealth splines	No	Yes	No	Yes
R^2	0.050	0.071	0.156	0.292
Number of observations	301,632	301,632	301,632	301,632
Panel B: Residual Regressions				
Activity			0.097	0.060
			(0.002)	(0.002)
R^2			0.010	0.005
Number of observations			301,632	301,632

and (3) correspond to the linear specifications and serve as benchmarks. We find that activity and participation are both positively related to age, labor income, and financial wealth. The estimated effects of being 10 years older are a 1.0-percentage-point higher activity rate and a 2.8-percentage-point higher participation rate. The effects of SEK 100,000 more in labor income are similar for activity and participation (1.5 and 1.1 percentage points higher, respectively), while the effects of SEK 100,000 more in financial wealth are lower for activity than for participation (0.5 and 2.8 percentage points higher, respectively).

The above estimates can be compared with the estimate in the residual regression (3), reported in Panel B. The results indicate that, after controlling for individual characteristics, there remains a strong positive relationship between activity in the pension system and stock market participation. Being an active investor in the pension system increases the likelihood of having equity exposure outside the pension system by 9.7 percentage points. This effect can in turn be compared with the 16.4-percentage-point difference in the unconditional participation rate between passive and active investors. Including a rich set of controls reduces the gap in participation rate by 6.7 percentage points, but it remains substantial.

In specifications (2) and (4) we let age, labor income, and financial wealth enter as piecewise linear splines. Even with these richer specifications, we find evidence of a strong positive relationship between activity and stock market participation. In particular, an active investor in the pension system is 6.0 percentage points more likely to participate in the stock market outside the pension system. Our results suggest that approximately 1/3 of the gap is driven by differences in unobservable characteristics. One such unobservable characteristic could be experience in making investment decisions.

The bottom-line finding from the above regressions is that activity in the pension system is strongly associated with equity exposure outside the pension system. Even when controlling for individual characteristics that correspond to the state variables of a standard life-cycle portfolio-choice model, the gap in stock market participation between passive and active investors is substantial. These findings have implications for the design of an optimal default fund. In addition, these findings underscore the importance of modeling limited stock market participation outside the pension system. Below, we design and calibrate our model to capture both the choice of being active in the pension system and the choice of participating in the stock market outside the pension system.

D.1. Industry

We include in the regressions fixed effects for education, geography, and industry. The strongest source of heterogeneity appears along the industry dimension. This is also evident from the unconditional statistics: employees of the financial sector have the highest rate of stock market participation and activity, which we interpret as a sign of familiarity with investing, while employees in the hotel and restaurant sector have the lowest rate of participation and activity. Unconditionally, the two groups differ by over 30 percentage points in activity and participation. In the Internet Appendix (Section II), we report for each industry the unconditional and conditional participation and activity rates from the regressions as well as the conditional correlation given by the industry-specific estimates of regression (3). Despite the large cross-sectional differences, our main finding holds across industries.

D.2. Real Estate Wealth

As real estate wealth constitutes a large share of investors' net worth, real estate owners may draw upon it during retirement. In the Internet Appendix (Section II), we report the equivalent of Tables I and II for renters and real estate owners separately. Importantly, renters have a lower rate of activity in the DC account than do real estate owners (28% versus 44%) and a lower participation rate (48% versus 66%). Renters also have less financial wealth relative to labor income. Vestman (2017) finds that these differences between real estate owners and renters are consistent with preference heterogeneity. Below, we explore the robustness of our model results to heterogeneity in net worth.

E. Heterogeneity among Passive Investors

In this section, we demonstrate that there is considerable heterogeneity among passive investors. Understanding how these investors differ from one another is important for the design of a default fund. Table III presents the distributions of variables for passive investors. Panel A shows that passive investors exist in all age categories and differ greatly in labor income, financial wealth, equity exposure, and net worth. Regarding the distribution in labor income, 25% of passive investors earn under SEK 99,911 whereas 25% earn over SEK 303,797. Looking at financial wealth, 25% of passive investors have under SEK 17,116 in financial wealth whereas 25% have SEK 218,505 or more, and looking at equity exposure, most passive investors have no equity exposure outside the pension system whereas 10% have at least 63.4% of their financial wealth allocated to equities. Finally, net worth is more than three times as great as financial wealth in the middle and the right tail of the distribution and is negative in the left tail.

In Panels B and C, passive investors are split into stock market participants and nonparticipants. We find that, while participants and nonparticipants differ little in age, they differ somewhat in labor income and considerably in financial wealth. The median nonparticipant earns 82% of what the median participant does. Furthermore, the median nonparticipant has just 15% of the financial wealth of the median participant, while only 10% of participants have less financial wealth than does the median nonparticipant. When we compare financial wealth to labor income, we find that stock market participants have financial wealth worth 1.4 years of labor income, while nonparticipants have financial wealth worth just five months of labor income. As participants have higher labor income, the average participating passive investor has 4.3 times as much financial wealth as does the average nonparticipating passive investor. Their difference in net worth is not quite as great, however, with the average participating passive investor having 3.2 times as much net worth as the average nonparticipating passive investor.

Taken together, the results in Table III suggest that there is considerable heterogeneity even among passive fund investors. Specifically, stock market

Table III
Distribution of Variables for Passive Investors

The table presents the averages of variables for passive investors by percentiles in 2007. At the end of 2007, the SEK/USD exchange rate was 6.47. Panel A corresponds to all passive investors. Panel B corresponds to passive investors who participate in the stock market. Panel C corresponds to passive investors who do not participate in the stock market. Labor income is gross annual labor income. A total of 182,487 investors are represented in Panel A, 83,053 in Panel B, and 99,434 in Panel C. Financial wealth includes financial wealth outside the pension system (i.e., bank accounts, direct bond and stock holdings, mutual funds) as well as balances in private pension accounts and capital insurance. Missing bank account balances are imputed to SEK 7,135. The equity share in Panel B corresponds to investors who participate in the stock market, where we assume that capital insurance and private pension accounts comprise 60% equities and 40% bonds; the equity share in Panel C is that of investors who do not participate in the stock market and by definition equals zero. Net worth is the sum of financial wealth and real estate wealth minus total debt (e.g., mortgages, credit card debt, and student loans).

	10%	25%	50%	75%	90%	Mean
Panel A: All Passive Investors						
Age	30	38	46	56	64	46.6
Labor income	0	99,911	225,373	303,797	401,252	224,526
Financial wealth	7,135	17,116	68,580	218,505	560,981	217,846
Equity share	0.000	0.000	0.000	0.401	0.634	0.196
Net worth	−151,186	−1,747	272,619	930,412	2,019,479	665,790
Panel B: Participants						
Age	32	39	48	58	65	48.3
Labor income	0	137,245	250,315	336,004	460,812	258,714
Financial wealth	26,272	68,468	176,367	432,910	934,804	374,888
Equity share	0.088	0.234	0.438	0.609	0.764	0.432
Net worth	−48,909	171,004	646,785	1,497,102	2,836,315	1,069,011
Panel C: Nonparticipants						
Age	30	36	44	54	62	45.2
Labor income	0	72,964	205,647	277,920	350,952	195,969
Financial wealth	7,135	7,135	26,996	83,589	207,063	86,676
Equity share	0.000	0.000	0.000	0.000	0.000	0.000
Net worth	−201,828	−51,387	58,646	466,923	1,147,239	328,996

participation serves as an indicator variable, as most participants are richer in terms of labor income, financial wealth, and net worth. These basic observations call into question the ability of a one-size-fits-all default fund to meet all investors' needs, which suggests in turn that it may be beneficial to carefully design the default fund to suit each investor's specific situation rather than impose one allocation on all investors.

IV. Model

Following the empirical analysis, we develop a life-cycle model of an investor to study the decision of whether to be active and to examine the optimal asset allocation of the default fund for passive investors. The model builds on the work of Viceira (2001), Cocco, Gomes, and Maenhout (2005), and Gomes and Michaelides (2005) and includes risky labor income, a consumption-savings choice, and a portfolio choice. We extend the standard model with a pension system in which individuals save in illiquid pension accounts, from which their pension is received as annuities. Importantly, we also extend the model with the endogenous decision of whether to remain in the default pension fund or opt out. Next, we describe the model's building blocks.

A. Demographics

We follow individuals from age 25 years until the end of their lives. End of life occurs at the latest at age 100, but could occur earlier as individuals face an age-specific survival rate, ϕ_t. The life cycle is split into a working phase and a retirement phase. From the ages of 25 to 64 years, individuals work and receive labor income exogenously. They then retire at age 65.

B. Preferences

Individuals have Epstein and Zin (1989) preferences over a single consumption good. At age t, each individual maximizes

$$U_t = \left(c_t^{1-\rho} + \beta \phi_t E_t \left[U_{t+1}^{1-\gamma} \right]^{\frac{1-\rho}{1-\gamma}} \right)^{\frac{1}{1-\rho}}, \tag{4}$$

with $U_T = c_T$, where β is the discount factor, $\psi = 1/\rho$ is the elasticity of intertemporal substitution, γ is the coefficient of relative risk aversion, and $t = 25, 26, \ldots, T$ with $T = 100$. For notational convenience, we define the operator $\mathcal{R}_t(U_{t+1}) \equiv E_t[U_{t+1}^{1-\gamma}]^{\frac{1}{1-\gamma}}$.

C. Labor Income

Let Y_{it} denote the labor income of employed individual i at age t and let $y_{it} = \ln(Y_{it})$. During the working phase (up to age 64 years), the individual faces a labor income process with a life-cycle trend and permanent income shocks:

$$y_{it} = g_t + z_{it}, \tag{5}$$

where

$$z_{it} = z_{it-1} + \eta_{it} + \theta \varepsilon_t. \tag{6}$$

In (5), the first term, g_t, is a hump-shaped life-cycle trend. The second term, z_{it}, is the permanent labor income component. The latter is subject to an idiosyncratic shock, η_{it}, which is distributed $\mathrm{N}(-\sigma_\eta^2/2, \sigma_\eta^2)$, and an aggregate shock, ε_t, which is distributed $\mathrm{N}(-\sigma_\varepsilon^2/2, \sigma_\varepsilon^2)$. The aggregate shock also affects the stock return, and θ determines the contemporaneous correlation between labor income and the stock return. We allow for heterogeneity in income at age 25 years by letting the initial persistent shock, z_{i25}, be distributed $\mathrm{N}(-\sigma_z^2/2, \sigma_z^2)$.

During retirement (from age 65 years and onwards), the individual has no labor income.[8] Pension income is often modeled as a deterministic replacement rate relative to the labor income just before retirement.[9] However, in our model, the replacement rate is endogenously determined. Apart from her own savings in (liquid) financial saving, the individual relies entirely on annuity payments from pension accounts. Below we discuss these accounts in detail.

D. Investor Heterogeneity

The decisions to opt out of the default pension fund and to participate in the stock market outside the pension system are endogenous. Both of these decisions are associated with frictions. To opt out, a one-time cost, κ_i^{DC}, must be paid; to enter the stock market, a one-time cost, κ_i, must be paid. A new feature of our model is that we allow for different magnitudes of these costs for different investors. The support of each cost's cross-sectional distribution as well as the correlation between them are set to match the shares of active and passive nonparticipants as well as the shares of active and passive participants in the data. The joint distribution of κ_i^{DC} and κ_i is nonparametric. The calibration section describes the process of determining the joint distribution. While the costs are known to each investor, in some analyses we treat the costs as unobserved by the designer of a default pension fund.

One-time costs of our kind are common in portfolio choice models (see, for example, Alan (2006), Gomes and Michaelides (2005, 2008)). We allow for a full cross-sectional joint distribution of costs over the two endogenous decisions. We justify the dispersion in costs with reference to the documented heterogeneity in financial literacy and financial sophistication (see Lusardi and Mitchell (2014) for an overview). Moreover, by introducing dispersion in the cost of participating in the stock market, we can better capture the life-cycle participation profile in the data.[10]

E. Opting Out and Participating in the Stock Market

The decision to opt out of the default pension fund is made at age 25 years and is associated with a binary state variable, I_i^{DC}. This treatment is consistent

[8] Hence, the retirement decision is not endogenous as in French and Jones (2011). More generally, we do not consider endogenous labor supply decisions as in Bodie, Merton, and Samuelson (1992) and Gomes, Kotlikoff, and Viceira (2008).

[9] One exception is that of Cocco and Lopes (2011), who model the preferred DB or DC pension plan for different investors.

[10] Fagereng, Gottlieb, and Guiso (2017) present an alternative setup to account for the empirical life-cycle profiles of portfolio choice. Their model involves a per-period cost and a probability of a large loss on equity investments. We consider a probability of a large return loss in robustness tests.

with the high degree of persistent inactivity among pension investors since the launch of the new system in 2000. Since the opt-out choice is made at age 25, there is a trivial law of motion for I_i^{DC} and hence it is denoted without a time subscript.

The decision to enter the stock market can be made at any life-cycle stage. Stock market participation is associated with a persistent binary state variable, I_{it}, that tracks the current status at age t. The law of motion for I_{it} is given by

$$I_{it} = \begin{cases} 1 & \text{if } I_{it-1} = 1 \quad \text{or} \quad \alpha_{it} > 0 \\ 0 & \text{otherwise,} \end{cases} \tag{7}$$

where α_{it} is the fraction of financial wealth invested in the stock market. The cost associated with stock market entry then becomes $\kappa_i(I_{it} - I_{it-1})$.

F. Asset Returns

The gross return on the stock market, R_{t+1}, follows the log-normal process

$$\ln(R_{t+1}) = \ln(R_f) + \mu + \varepsilon_{t+1}, \tag{8}$$

where R_f is the gross return on a risk-free bond and μ is the equity premium. Recall that the shock, ε_t, is distributed $\mathrm{N}(-\sigma_\varepsilon^2/2, \sigma_\varepsilon^2)$, so $E_t(R_{t+1} - R_f) = \mu$. Also recall that ε_t affects labor income in (6), and that the correlation between stock returns and labor income is governed by the parameter θ.

G. Three Savings Accounts

Each individual has three financial savings accounts: (i) a liquid account outside the pension system (referred to as financial wealth), (ii) a fully funded DC account in the pension system, and (iii) a notional account belonging to the pension system. The notional account, which constitutes the basis of the pension, is based on income and evolves at the rate of the risk-free bond. The DC account, which corresponds to the default fund we wish to design, is also income based but the investor can choose how to allocate between bonds and stocks.

The account outside the pension system is accessible at any time. Each individual chooses freely how much to save and withdraw from it. In contrast, the contributions to the pension accounts during the working phase are determined by the pension policy (rather than by the individual) and are accessible only in the form of annuities during retirement. Importantly, the two pension accounts include insurance against longevity risk.

G.1. Financial Wealth

The individual starts the first year of the working phase with financial wealth, A_{i25}, outside the pension system. The log of initial financial wealth is distributed $N(\mu_A - \sigma_A^2/2, \sigma_A^2)$. In each subsequent year, the individual can freely access her financial wealth, make deposits, and choose the fraction to be invested in risk-free bonds and in the stock market. However, the individual cannot borrow

$$A_{it} \geq 0, \tag{9}$$

and the equity share is restricted to be between zero and one,

$$\alpha_{it} \in [0, 1]. \tag{10}$$

Taken together, (9) and (10) imply that individuals cannot borrow at the risk-free rate and cannot short the stock market or take leveraged positions in it.

The individual's cash on hand (i.e., the sum of financial wealth and labor income) evolves according to

$$X_{it+1} = A_{it}\left(R_f + \alpha_{it}(R_{t+1} - R_f)\right) + Y_{it+1}. \tag{11}$$

Supported by the analysis in Fischer, Kraft, and Munk (2013), we do not model taxes on capital gains.

G.2. DC Account

Inside the pension system, each individual has a DC account with a balance of A_{it}^{DC}. During the working phase, the contribution rate equals λ^{DC}.[11]

The investor cannot short the stock market or take leveraged positions in it:

$$\alpha_{it}^{\mathrm{DC}} \in [0, 1]. \tag{12}$$

Before retirement, the law of motion for the DC account balance is

$$A_{it+1}^{\mathrm{DC}} = A_{it}^{\mathrm{DC}}\left(R_f + \alpha_{it}^{\mathrm{DC}}(R_{t+1} - R_f)\right) + \lambda^{\mathrm{DC}} Y_{it}. \tag{13}$$

Upon retirement at age 65, withdrawal starts. We assume that the investor is allowed to make a one-time decision on her equity exposure over the remainder of her life (i.e., $\alpha_{i65}^{\mathrm{DC}} = \alpha_{i66}^{\mathrm{DC}} = \cdots = \alpha_{i100}^{\mathrm{DC}}$). This variable therefore becomes a state variable.

G.3. Asset Allocation in the DC Account during Working Life

We consider different rules for $\alpha_{it}^{\mathrm{DC}}$ prior to retirement. Active investors who opt out are assumed to choose the equity share in the DC account fully rationally. Below we outline this dynamic programming problem in detail.

[11] In line with the Swedish pension system, we implement the contribution as an employer tax. This means that the contributions do not show up as withdrawals from gross labor income in the individual's budget constraint. This is consistent with our calibration of the labor income process to micro data (i.e., our measure of gross labor income is net of the employer tax).

It is common to formulate investment rules that depend on age. One such rule is to invest 100% minus one's age in equity and the remainder in bonds. According to this rule, a 30-year-old would invest 70% in equities while a 70-year-old would invest 30% in equities. We refer to this as the "100-minus-age" rule. This rule can be modified to have different equity exposures at the beginning of the working phase and in retirement. We first assume that default investors are exposed to an age-based equity share of "100-minus-age" during the working phase and 35% in retirement. We then contrast the consequences of this design to three alternatives:

1. the optimal equity share conditioned on all state variables in the model (i.e., apart from the cost associated with opting out, it is equivalent to the allocation of an active investor who opts out);
2. a rule of thumb conditioned on a subset of observable characteristics that appear as state variables; and
3. the average optimal age-based equity share (i.e., a glide path conditioned only on age and equal to the average optimal equity share).

G.4. Notional Account

The law of motion for the notional account balance during the working phase is given by

$$A^{\mathrm{N}}_{it+1} = A^{\mathrm{N}}_{it} R_f + \lambda^{\mathrm{N}} Y_{it}, \tag{14}$$

where λ^{N} is the contribution rate for the notional account.

To economize on state variables, we use z_{i64} to approximate the notional account balance at retirement. This approximation is based on simulations of (5), (6), (8), and (14) to obtain the best fit between z_{i64} and A^{N}_{i64} using regression analysis. This approximation works well. We provide further details in the Internet Appendix (Section III).

G.5. Annuitization of the Pension Accounts

Upon retirement at age 65 years, the DC account and the notional account are converted into two actuarially fair lifelong annuities. These insure against longevity risk through within-cohort transfers from individuals who die to surviving individuals. The notional account provides a fixed annuity with a guaranteed minimum. If the account balance is lower than what is required to meet the guaranteed level at age 65, the individual receives the remainder at age 65 in the form of a one-time transfer from the government. The annuity from the DC account is variable and depends on the choice of equity exposure as well as realized returns. In expectation, the individual will receive a constant payment each year. We abstract from different tax rates between realized capital gains outside the pension system and the annuity payments inside the pension system.

H. Individual's Problem

Next we describe the individual's problem. To simplify the notation, we suppress the subscript i. In the Internet Appendix (Section IV), we describe the method for solving the investor's problem.

H.1. Be Active or Stay in the Default Fund

Let $V_t(X_t, A_t^{\mathrm{DC}}, z_t, \kappa, \kappa^{\mathrm{DC}}, I_{t-1}, I^{\mathrm{DC}})$ be the value of an individual of age t with cash on hand X_t, DC account balance A_t^{DC}, persistent income component z_t, cost of stock market entry κ, cost of opting out κ^{DC}, stock market participation experience I_{t-1}, and activity in the DC account I^{DC}.

The individual chooses whether to remain in the default fund ($I^{\mathrm{DC}} = 0$) or to opt out ($I^{\mathrm{DC}} = 1$):

$$\max_{I^{\mathrm{DC}} \in \{0,1\}} \left\{ V_{25}\left(X_t, 0, z_{25}, \kappa, \kappa^{\mathrm{DC}}, 0, 0\right), V_{25}\left(X_t - \kappa^{\mathrm{DC}}, 0, z_{25}, \kappa, \kappa^{\mathrm{DC}}, 0, 1\right) \right\}.$$

The decision to be active thus comes at a cost. The trade-off arises because staying in the default fund is costless but implies a suboptimal asset allocation. Unlike the model of Carroll et al. (2009), the one-time opportunity to opt out implies that there is no option value associated with waiting to take action.[12]

H.2. Active Investor's Problem

The following describes the individual's problem when the equity share in the DC account is chosen optimally (i.e., conditional on all state variables) subject to paying the cost κ^{DC} (i.e., $I^{\mathrm{DC}} = 1$). We refer to this as the active investors' dynamic programming problem. For brevity, we introduce the notation $\Psi_t = (X_t, A_t^{\mathrm{DC}}, z_t)$.[13]

H.3. Participant's Problem

An active investor who has already entered the stock market solves the problem

$$V_t\left(\Psi_t, \kappa, \kappa^{\mathrm{DC}}, 1, 1\right) = \max_{A_t, \alpha_t, \alpha_t^{\mathrm{DC}}} \left\{ \left((X_t - A_t)^{1-\rho} + \beta \phi_t \mathcal{R}_t\left(V_{t+1}\left(\Psi_{t+1}, \kappa, \kappa^{\mathrm{DC}}, 1, 1\right)\right)^{1-\rho} \right)^{\frac{1}{1-\rho}} \right\}$$

subject to equations (5) to (13).

[12] Apart from simplicity, this model choice can be broadly justified by the finding of Dahlquist, Martinez, and Söderlind (2017) that 69% of premium pension investors made no fund changes to their portfolio of funds between 2000 and 2010.

[13] Note that, compared with working life, ages 65 years or older carry the additional state variable $\alpha_{65}^{\mathrm{DC}}$. For simplicity, we omit this variable from the value function.

H.4. Stock Market Entrant's Problem

Let $V_t^{+}(\Psi_t, \kappa, \kappa^{\mathrm{DC}}, 0, 1)$ be the value for an active investor with no previous stock market participation experience who decides to participate at age t. This value is formulated as

$$V_t^{+}\left(\Psi_t, \kappa, \kappa^{\mathrm{DC}}, 0, 1\right) = \max_{A_t, \alpha_t, \alpha_t^{\mathrm{DC}}} \left\{ \left((X_t - A_t - \kappa)^{1-\rho} + \beta \phi_t \mathcal{R}_t \left(V_{t+1}\left(\Psi_{t+1}, \kappa, \kappa^{\mathrm{DC}}, 1, 1\right)\right)^{1-\rho} \right)^{\frac{1}{1-\rho}} \right\}$$

subject to equations (5) to (13).

H.5. Nonparticipant's Problem

Let $V_t^{-}(\Psi_t, \kappa, \kappa^{\mathrm{DC}}, 0, 1)$ be the value for an active investor with no previous stock market participation experience who decides not to participate at age t. This value is formulated as

$$V_t^{-}\left(\Psi_t, \kappa, \kappa^{\mathrm{DC}}, 0, 1\right) = \max_{A_t, \alpha_t^{\mathrm{DC}}} \left\{ \left((X_t - A_t)^{1-\rho} + \beta \phi_t \mathcal{R}_t \left(V_{t+1}\left(\Psi_{t+1}, \kappa, \kappa^{\mathrm{DC}}, 0, 1\right)\right)^{1-\rho} \right)^{\frac{1}{1-\rho}} \right\}$$

subject to equations (5) to (13).

Note that as $\alpha_t = 0$, the return on financial wealth is simply R_f.

H.6. Optimal Stock Market Entry

Given the entrant's and nonparticipant's problems, stock market entry is given by

$$V_t\left(X_t, A_t^{\mathrm{DC}}, z_t, \kappa, \kappa^{\mathrm{DC}}, 0, 1\right) = \max_{I_t \in \{0,1\}} \left\{ V_t^{-}\left(X_t, A_t^{\mathrm{DC}}, z_t, \kappa, \kappa^{\mathrm{DC}}, 0, 1\right), V_t^{+}\left(X_t - \kappa, A_t^{\mathrm{DC}}, z_t, \kappa, \kappa^{\mathrm{DC}}, 0, 1\right) \right\}.$$

H.7. Default Investor's Problem

The default investor's problem is almost identical to the active investor's problem, but with two differences. First, common to all default fund schemes is that default investors do not incur the cost κ^{DC}. Second, α_t^{DC} is sometimes determined differently. If the equity share of the default fund is a function only of age (the unconditional optimal glide path, or "100-minus-age") or a subset of state variables (a rule of thumb), then the asset allocation is suboptimal relative to that implied by the active investor's dynamic programming problem. Only if the equity share of the default fund is fully customized and conditioned on all state variables is the default investor's asset allocation identical to that of the active investors.

Table IV

Model Parameters

The table presents the parameter values of the model. *: The parameter value is determined by simulating the model. The labor income profiles are discussed in detail in the text. The survival rates are computed from unisex statistics provided by Statistics Sweden. At the end of 2007, the SEK/USD exchange rate was 6.47.

	Notation	Value
Returns		
Gross risk-free rate	R_f	1.00
Equity premium	μ	0.04
Standard deviation of stock market return	σ_ε	0.18
Labor income and financial wealth		
Standard deviation of idiosyncratic labor income shock	σ_η	0.072
Weight of stock market shock in labor income	θ	0.040
Standard deviation of initial labor income	σ_z	0.366
Standard deviation of initial financial wealth	σ_A	1.392
Mean of initial financial wealth		76,800
Contribution rates in pension accounts		
DC account	λ^{DC}	7%
Notional account	λ^{N}	16%
Life-cycle profiles		
Labor-income profile	g_t	–
Survival rates	ϕ_t	–
Preferences and stock market participation cost		
Elasticity of intertemporal substitution	$1/\rho$	0.500
Discount factor*	β	0.933
Relative risk aversion*	γ	14
Ceiling for opt-out cost*	$\overline{\kappa}^{DC}$	3,600
Ceiling for stock market entry cost*	$\overline{\kappa}$	15,600
Number of layers in the cost distribution*		3

H.8. Portfolio Choice Outside the Pension System

In the main analysis, we assume full rationality with respect to investment behavior outside the pension system. In robustness tests, we consider the consequences of investment mistakes.

I. Calibration

In this section, we describe our calibration strategy. Table IV reports the values of key parameters. Most parameters are set either according to existing literature or to match Swedish institutional details. We briefly describe the calibration strategy below and provide a more detailed discussion in the Internet Appendix (Section V).

First, we set the equity premium to 4% per year and the standard deviation of the stock market return to 18% per year. We set the simple risk-free rate to zero.

Table V

Matched Moments in the Data and Model

The table presents matched moments in the data and model. We consider data from the working phase. Activity in the data corresponds to opting out in the model. The table implies that the share of passive (default) investors is 0.605 (0.330 + 0.275) in the data and 0.587 (0.316 + 0.271) in the model; the share of nonparticipating investors is 0.481 (0.151 + 0.330) in the data and 0.474 (0.158 + 0.316) in the model.

	Data	Model
Financial wealth-to-labor income ratio	0.922	0.921
Equity share (conditional)	0.454	0.519
Active (opting out)/nonparticipation	0.151	0.158
Active (opting out)/participation	0.244	0.255
Passive (default)/nonparticipation	0.330	0.316
Passive (default)/participation	0.275	0.271

Second, we set labor income according to Swedish data. We find that the standard deviation of permanent labor income equals 0.072. We set the one-year correlation between permanent income growth and stock market returns to 10%. This corresponds to a θ of 0.040. The mean financial wealth for 25-year-old default investors is set to SEK 76,800. The cross-sectional standard deviations are set to 0.366 (σ_z) and 1.392 (σ_A) to match the data for 25-year-old individuals.

Third, we consider the contribution rates. We set the contribution rate for the notional account to 16% and that for the DC account to 7%. These choices mirror the premium pension account with a contribution rate of 2.5% and the occupational pension account with a typical contribution rate of 4.5%.

Fourth, we determine an annuity factor of 5.6% of the notional account balance at age 65 years. The annuity factor of the DC account depends on risk-taking at age 65. Both factors are based on ϕ_t, which in turn is based on the unisex mortality table of Statistics Sweden.

Fifth, we set the elasticity of intertemporal substitution to 0.5.

Finally, we set the DC equity share profile of the calibration to be a linear profile such that the equity share equals "100-minus-age" during working life and 35% over retirement. Rules of thumb of this kind are extremely widespread.

I.1. Parameters Matched to Moments

Three sets of parameters, marked by an asterisk "*" in Table IV, are chosen to match moments from the working phase. Table V reports these moments in the data and model.[14]

[14] Note that we match the model to data from 2007. This does not allow us to control for cohort or time effects when we report the age profiles, unlike, for example, Ameriks and Zeldes (2004). However, Vestman (2017) finds that controlling for either cohort or time effects (one at a time) when estimating age profiles for labor income and financial wealth matters little.

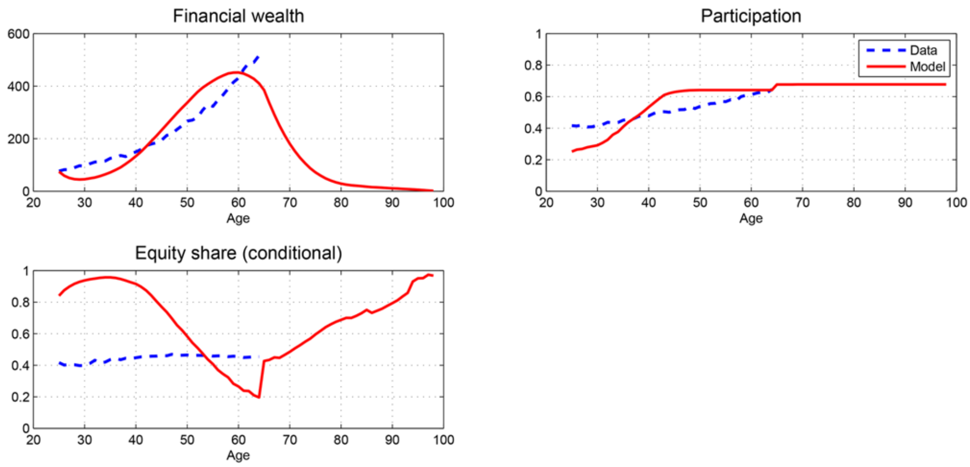

Figure 1. Calibration and model fit. The figure shows the fit of the model to the data. The model simulation is based on 50 economies and 11,500 individuals. Financial wealth is expressed in SEK 1,000s. (Color figure can be viewed at wileyonlinelibrary.com)

First, the discount factor, β, is calibrated to match the ratio of financial wealth to labor income of 0.922. A discount factor of 0.933 fits the ratio well. The top-left panel of Figure 1 shows the full life-cycle profile of financial wealth. The model fits financial wealth reasonably well, undershooting somewhat up to age 42 and overshooting after that.

Second, the relative risk aversion coefficient, γ, determines the conditional equity share. We weight the equity share of each age group by its financial wealth. A relative risk aversion of 14 provides a reasonable fit. We consider an equity premium of 2%, which allows for a lower relative risk aversion coefficient, in robustness tests. The value-weighted conditional equity share is 0.454 in the data and 0.519 in the model. The lower-left panel of Figure 1 shows the life-cycle profile. The model overshoots early in the life cycle and undershoots over the 10 years before retirement. This is a common feature of life-cycle portfolio choice models. We consider alternative specifications in robustness tests in which the investor makes random allocation mistakes or has the equity share found in the data. We are reluctant to increase relative risk aversion further, as this would lead to a worse discrepancy close to retirement age. In the model there is a noticeable increase in the equity share after age 70 years. However, if value weighted, this increase is negligible as financial wealth is then small.

Third, we calibrate the joint distribution of the two costs, κ and κ^{DC}, to the joint distribution of active/passive and participating/nonparticipating investors, which is a total of four moments (they sum to one). For computational ease, we approximate each distribution with five equally spaced values, which enables us to include up to 25 combinations, forming a 5×5 matrix. We give each included type the same weight. For each cost, we let the lower support be given by zero. The upper support of κ is determined by the share of nonparticipation in the data (48.1%) and the upper support of κ^{DC} is determined by the share of passive investors (60.5%). These shares imply an upper support of κ equal to SEK 15,600 and an upper support of κ^{DC} equal to SEK 3,600. The cost associated with opting out is smaller because the benefits of doing so mainly accrue in 40 years time. The shares of investors who are active and participate (24.4%) and who do not participate and are passive (33.0%) determine the correlation between the two costs. If we included all 25 combinations, the correlation between κ and κ^{DC} would be zero and the correlation between nonparticipation and default investing would be determined entirely by observable characteristics such as financial wealth and labor income. If we included only the diagonal elements of the 5×5 matrix, the correlation between the costs would be one. To systematically determine which of the 25 types of combinations of κ and κ^{DC} to include, we start from the case of a perfect correlation along the diagonal of the square matrix and then add types in layers progressively further from the diagonal to achieve the best fit of the shares of active participants and passive nonparticipants. The best fit is obtained when including three layers on each side of the diagonal (i.e., including 23 types). The matrix below illustrates this process:

$\overline{\kappa}^{\mathrm{DC}}$	4	**3**	**2**	**1**	**0**
	3	**2**	**1**	**0**	**1**
	2	**1**	**0**	**1**	**2**
	1	**0**	**1**	**2**	**3**
0	**0**	**1**	**2**	**3**	4
	0				$\overline{\kappa}$

where the elements on the diagonal and the three layers on each side of the diagonal are in bold. Equally weighting these 23 types implies a correlation between κ and κ^{DC} of 0.2. Moreover, as we use a square matrix, the two marginal distributions have the same shape and are symmetric around their means and modes (equal to SEK 7,800 for the participation cost and SEK 1,800 for the opt-out cost). We find our modeling approach appealing as it lets us minimize the costs for the average investor (see Vissing-Jørgensen (2002)).

I.2. Simulation Method

There are two main sources of risk in our model: (i) aggregate equity returns and (ii) idiosyncratic labor income shocks. Our simulation method lets us separately study the two sources of risk. For each of the 23 types, we consider 500 individuals with different idiosyncratic labor income shocks, for a total of 11,500 individuals in an economy. The 23 individual types share the same income realization but have different costs. Strictly speaking, an economy is a single birth cohort, which we follow over its life. The economy faces one equity return realization of 75 annual returns, common to all individuals in the economy. We simulate a total of 50 economies.

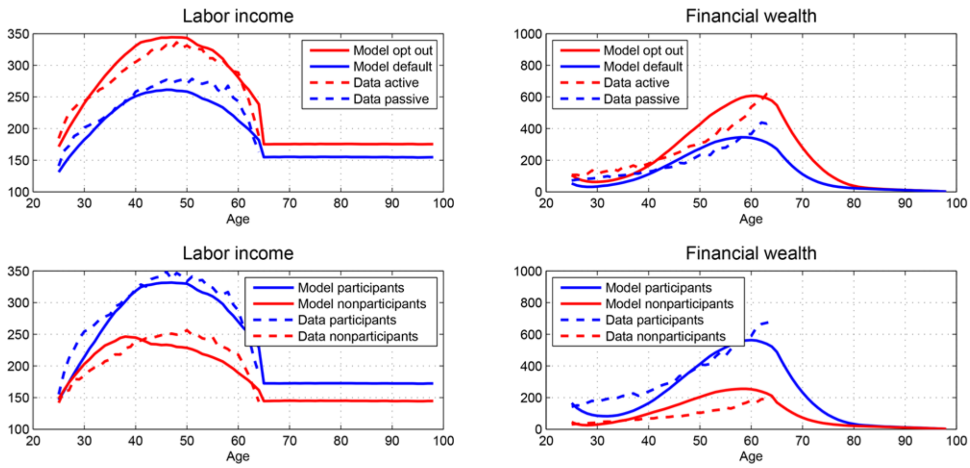

Figure 2. Model fit of participants/nonparticipants and default/opt-out investors. The figure shows the average labor income and financial wealth (both in SEK 1,000s) of default/opt-out and participant/nonparticipant investors. The separation of default/opt-out investors is a result of an endogenous choice when investors are exposed to the "100-minus-age" default design (as in the calibration). (Color figure can be viewed at wileyonlinelibrary.com)

When we take the average for each individual over the 50 economies, we obtain ex ante life-cycle profiles of 11,500 individuals; this distribution represents the inequality across individuals. When we take the average for each economy over the 11,500 individuals, we can analyze the role of aggregate equity risk. When we compute averages over both sources of risk, we obtain unconditional averages, which we simply refer to as averages.[15]

I.3. Model Fit

Figure 2 demonstrates the model's ability to endogenously sort individuals in terms of average labor income and financial wealth. The top-left panel shows that the model can produce a gap in labor income between opt-out and default investors that is very similar to the data. The top-right panel shows that the model yields a similar gap in financial wealth between opt-out and default investors. The opt-out and default investors result from endogenous choice when investors are exposed to "100-minus-age" (as in the calibration). The bottom-left panel plots labor income for participants and nonparticipants. The gap in the model is qualitatively very similar to that in the data (but widens a little too much late in the working phase). The bottom-right panel shows that the model also generates a substantial gap in financial wealth, starting

[15] For every economy, the same idiosyncratic income shocks are used. The cross-sectional average of these shocks is zero for each year. Furthermore, we reuse the idiosyncratic income shocks and stock market returns for all cost types and all designs of the default fund. We also reuse initial draws of z_{i25} and A_{i25}. This simulation method is similar to that of Campbell and Cocco (2015), who also distinguish between aggregate and idiosyncratic shocks.

from age 40 years. We find the fit remarkable given that neither the labor income nor the financial wealth of any subgroup of investors is targeted in the calibration.

V. Optimal Design

In this section, we first discuss who the default investors are and the optimal design for these investors. We then consider how the optimal asset allocation responds to realized equity returns and to labor income shocks. For simplicity, we first let the default investors arise from the "100-minus-age" allocation. We then illustrate the optimal allocation for different groups of default investors that have endogenously arisen under other default designs. For each of these designs and groups of default investors, we report the welfare implications of implementing an even more customized default. The optimal design is a counterfactual outcome: it answers the question of which asset allocation a given group of default investors would prefer the most.

A. Who Are the Default Investors?

Our model allows the opt-out/default choice to be shaped by both observable and unobservable characteristics, as in the data. We begin by reporting the effect of these characteristics on this choice.

Taking opt-out and default investors together, the average cost of opting out is SEK 1,800; however, for default investors the average is SEK 2,500 and for opt-out investors it is SEK 800. In addition, there is substantial variation within the investor groups. We also find a substitution effect between the two costs, whereby the share of opt-out investors at a given opt-out cost increases with the participation cost, which suggests that financial wealth and the DC account are substitutes. The Internet Appendix (Section VI) reports the share of opt-out investors for each of the 23 cost types.

B. Optimal Asset Allocation for Default and Opt-Out Investors

Figure 3 provides averages of all model outcomes for default and opt-out investors under the optimal asset allocation. The groups of default and opt-out investors are a result of an endogenous choice when exposed to the "100-minus-age" default design. For the default group, we report the paths associated with their (counterfactual) optimal asset allocation.

The top-left panel plots labor income during the working phase and pension (i.e., annuities from the DC and notional accounts) during retirement. We find that labor income is substantially higher for opt-out investors, indicating that labor income matters for the opt-out decision. The top-right panel plots consumption, which is hump shaped as individuals do not fully smooth their consumption.

The three following panels plot the notional account, DC account, and financial wealth, all of which are built up during the working phase and then

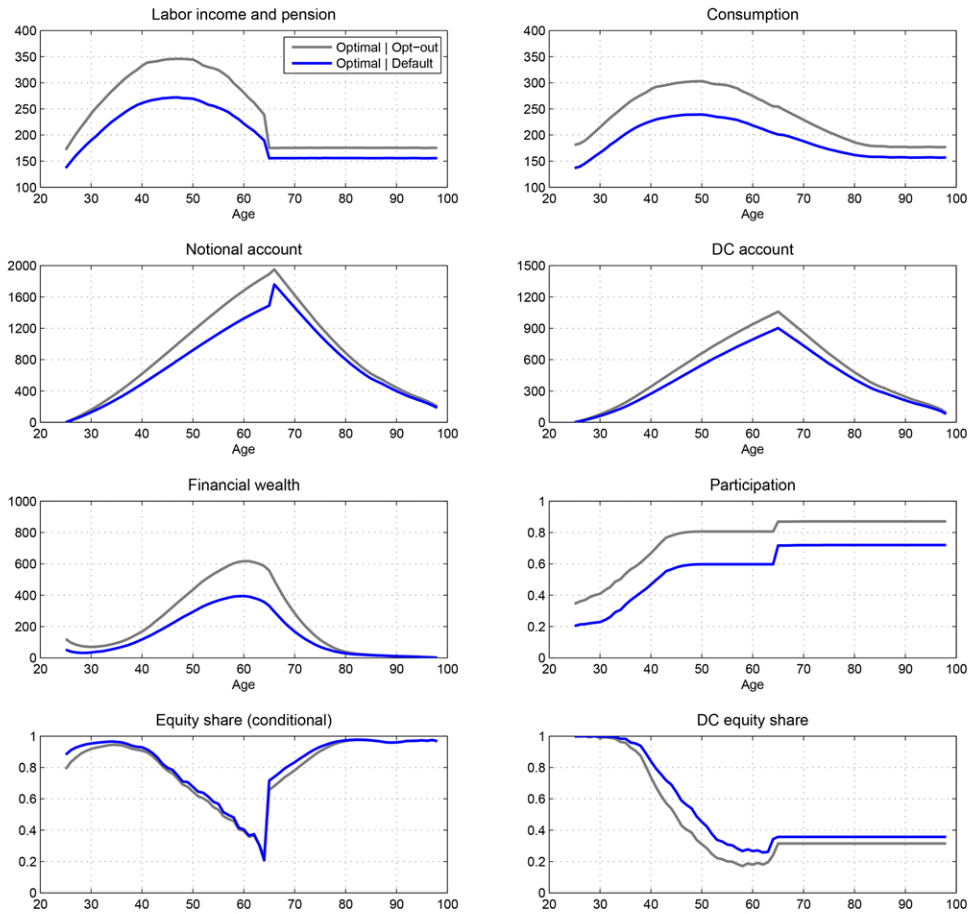

Figure 3. Averages for default and opt-out investors. The figure shows averages over 50 economies and 11,500 individuals for the optimal asset allocation of opt-out and default investors (4,754 vs. 6,746 individuals). The two groups are a result of an endogenous choice when investors are exposed to the "100-minus-age" default design (as in the calibration). Labor income and pension, consumption, notional and DC accounts, and financial wealth are expressed in SEK 1,000s. (Color figure can be viewed at wileyonlinelibrary.com)

depleted. The high contribution rates for the two pension accounts make their balances large relative to financial wealth even at a young age. Already before age 30 years, the DC account is as large as financial wealth. The importance of the DC account then increases and at age 65 it is 2.9 times as large as financial wealth for default investors. Note that the annuity floor, which is more important for default investors, is manifested as a jump in the profile for the notional account between ages 64 and 65.

The magnitude of the DC account relative to both financial wealth and the notional account illustrates the potency of the optimal asset allocation of the default fund: total equity exposure is essentially determined by the equity share in the DC account. Financial wealth serves mainly as a buffer for precautionary savings motives.

The third panel on the right plots the stock-market participation rate for default and opt-out investors. Default investors display a gap relative to opt-out investors of at most 20 percentage points during working life.

The bottom-left panel plots the equity share in financial wealth (outside the pension system) conditional on participation. It first increases slightly and then decreases until retirement, when it jumps. The increase up to age 35 years is driven by selection. As wealth-poorer households enter, they can tolerate a higher conditional equity share. Around age 40, the sample of participants stabilizes and the conditional equity share gradually falls. As the present value of labor income decreases and financial wealth increases, a high equity share cannot be tolerated (Merton (1971), Cocco, Gomes, and Maenhout (2005)). After retirement, individuals tolerate a somewhat higher equity exposure. Note that the increase in the conditional equity share after retirement is economically not as important, as financial wealth is then low.

Finally, the bottom-right panel plots the DC equity share for default and opt-out investors. At age 25 years it is 100%. It remains high until age 35, when it starts to decrease almost linearly. Notably, the change is greater for opt-out than default investors. By age 45 there is a gap of 15 percentage points between default and opt-out investors, with default investors being on a more aggressive path than opt-out investors. The main takeaway is that the endogenous selection into the default fund has implications for the optimal DC equity share. Starting at age 35, default investors prefer a more aggressive allocation than do opt-out investors. The average DC equity share fits well with target-date (or life-cycle) funds offered by mutual fund families such as Fidelity and Vanguard, as the equity share in their funds is typically around 80% to 90% until 30 years before retirement (at age 35 in our model), when the equity share starts to decline by 1.5 to 2 percentage points per year until retirement (at age 65 in our model). However, while the average equity share of the model fits well with the allocation of target-date funds, the model average masks considerable variation, which we explore in the remainder of the paper.

C. Equity Risk and Inequality

Figure 4 plots the aggregate equity risk and inequality implied by the optimal asset allocation for default investors. The panels to the left show averages over individuals, highlighting the equity risk; the panels to the right show averages over economies, highlighting the inequality across individuals arising from idiosyncratic labor income shocks. We sort the variables by the DC equity share in each of the top panels, and maintain that sorting in the remaining panels. As before, the default investor outcomes are the counterfactual ones associated with the optimal DC equity share when investors are exposed to a default design equal to "100-minus-age."

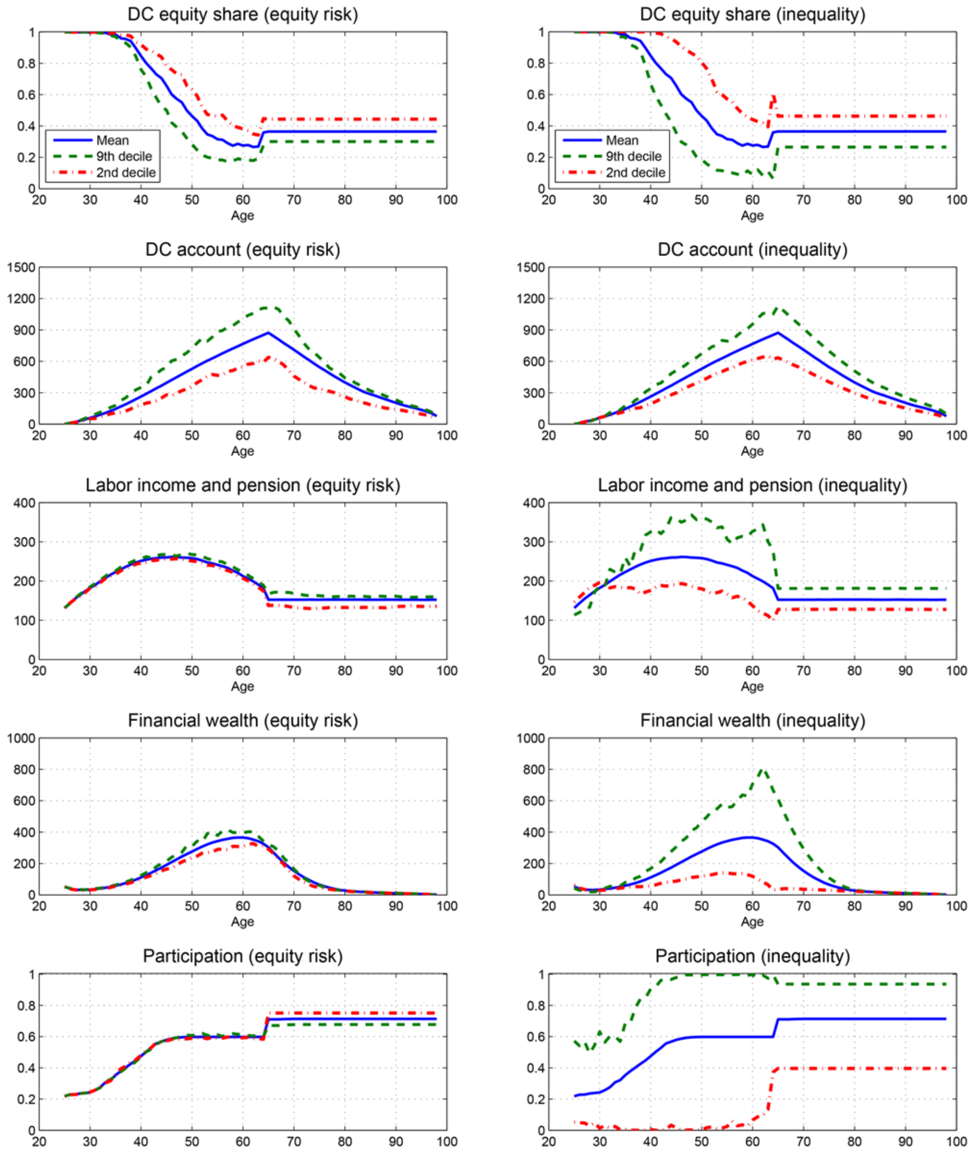

Figure 4. Aggregate equity risk and inequality implied by the optimal asset allocation. The figure shows the aggregate equity risk and inequality for the optimal asset allocation of default investors. The simulation is based on 50 economies and 11,500 individuals. The left panels show how the averages vary over 50 economies. The second decile corresponds to the average of economies 6 to 10 (sorted). The ninth decile corresponds to the average of economies 41 to 45 (sorted). The right panels show how the averages vary over individuals who endogenously become default investors. A decile is then 1/10 of these default investors. The same economies and individuals are not tracked over time, that is, the sorting at one age is independent of the sorting at another age. The DC account, labor income and pension, and financial wealth are expressed in SEK 1,000s. (Color figure can be viewed at wileyonlinelibrary.com)

The top-left panel shows how the DC equity share varies over the economies, that is, how it varies with realized equity returns. The second decile indicates that, with a probability of at least 10%, the DC equity share exceeds 34% throughout the working phase (jumping to approximately 44% at retirement). The ninth decile indicates the opposite pattern: with a probability of at least 10%, the DC equity share decreases to under 20% before retirement. The panel below plots the corresponding values for the DC account. It indicates a strong negative correlation between the DC equity share and the DC account balance, with a high equity share corresponding to a low account balance and vice versa. The remaining three panels to the left plot the corresponding values for labor income and pension, financial wealth, and stock market participation. None of these variables covaries as strongly with the DC equity share as does the DC account balance.

Given that the DC equity share correlates negatively with the DC account balance, while labor income (and hence contributions to the DC account) does not, the above analysis suggests that realized equity returns affect the optimal asset allocation through active rebalancing. As returns exceed expectations, it is optimal to invest less in equity and vice versa.

The top-right panel plots the inequality in the DC equity share. The first decile has the highest DC equity share and the tenth the lowest. We report the second and ninth deciles. The second decile has an average DC equity share that stays above 60% until age 53 years, after which it declines to 39% just before retirement. The ninth decile has an average DC equity share of 18% at age 50, which declines to below 9% just before retirement. The gap between the second and ninth deciles starts to widen at age 40, when it exceeds 30 percentage points; it is 60 percentage points among 50-year-old investors.

The four panels below show how the inequality in DC equity shares relates to other characteristics. Individuals with a high optimal DC equity share have low DC account balances, are somewhat income poor, and are unlikely to participate in the stock market, while individuals with a low optimal DC equity share have high DC account balances, are somewhat income rich, and are likely to participate in the stock market.[16]

To sum up, variation across economies implies that equity return realizations matter for the DC equity share. This means that different birth cohorts have different optimal allocations at the same age. Moreover, the large cross-sectional dispersion in optimal equity shares emphasizes the potential of an asset allocation conditional on investor-specific characteristics. In other words, different default investors have different needs.

[16] We also plot the ratio of the DC account balance to labor income. For default investors under 50 years old, there is little difference in this ratio between the second and ninth deciles, suggesting a selection effect in terms of participation. Later in life, starting from age 50, the second decile has a low ratio and the ninth decile a high ratio, consistent with the standard mechanism already alluded to.

D. Mass Customization: A Rule of Thumb Beyond Age

In this section we approximate the optimal design with regressions on observable characteristics. Such regressions are a means to create a rule of thumb that effectively allows rule-based mass customization or robo-advising.

To complement our previous graphical illustration of equity risk and inequality, we regress the optimal equity share of default investors on their characteristics. More specifically, we run the following regression on model-generated data:

$$\alpha_{it}^{\mathrm{DC}} = \beta_0 + \beta_1 t + \beta_2 A_{it} + \beta_3 A_{it}^{\mathrm{DC}} + \beta_4 Y_{it} + \beta_5 I_{it} + \varepsilon_{it}, \tag{15}$$

where the dependent variable is the optimal DC equity share of individual i of age t and all covariates are state variables of the model. Note that A_{it} and A_{it}^{DC} are functions of both idiosyncratic income shocks and aggregate equity returns. We do not include the costs, κ_i and κ_i^{DC}, as they would be unobservable in actual data.

We run the regression on individuals during their working phase. Note that the R^2 in the regression captures the efficiency of the investment rule relative to the optimal equity share conditioned on all state variables in the model.[17]

This analysis relates to Merton (1971), who derives the intertemporal hedging motive arising from the present discounted value of labor income. Cocco, Gomes, and Maenhout (2005) discuss the role of financial wealth relative to total wealth (including the present value of labor income) when labor income is uninsurable. In our model the value of the three accounts (A_{it}, A_{it}^{DC}, and A_{it}^{N}) and the present value of labor income guide optimal equity shares inside and outside the pension system. The purpose of our analysis is to obtain an asset allocation rule that is implementable for the designer of a default pension fund. We therefore focus on different subsets of the state variables and do not include wealth ratios in the analysis. In related work, Dammon, Spatt, and Zhang (2004) focus on the optimal equity share in a tax-deferrable (retirement) account as a function of age and account balance.

Table VI reports the regression results using different specifications. Specification (1) mimics the simple age-based investment rule. The results suggest that individuals should decrease their DC equity exposure by 2.4 percentage points every year. This linear specification is admittedly a crude specification, because it results in many young individuals being forced into a DC equity share of 100%. Indeed, the estimated intercept implies that the predicted DC equity share for a 25-year-old is 114.6%. Nevertheless, the interpretation is that a better rule for the DC equity share would be to have it at 100% until about age 30 and thereafter let it fall by 2.4 percentage points per year. Note that this is a steeper reduction in equity exposure over time than that of the "100-minus-age" rule. Interestingly, the R^2 of our rule is as high as 63.0%. Specifications with a polynomial in age improve the R^2 only marginally.

[17] We also consider regression specifications in which income and asset values are in logs rather than levels. They consistently perform worse, in terms of both R^2s and welfare gains, when implemented as a rule of thumb in the model.

Table VI

DC Account Equity Share in Model-Simulated Data

The table presents the results of regressions of the model's optimal DC equity share on some of the model's state variables. The simulated data are based on 50 economies, each of which has 11,500 investors (500 individuals each with 23 combinations of stock market participation and opt-out costs) who work for 40 years. The number of default investors is endogenous (here 58.7% of all investors), giving a total of 13,492,000 simulated observations in each of the regressions. Labor income, financial wealth, and DC account balance are scaled down by 1,000,000. Standard errors, robust to conditional heteroskedasticity and clustered over economy and individual, are reported in parentheses.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Constant	1.746	1.873	1.585	1.738	1.313	1.347	1.266
	(0.016)	(0.015)	(0.018)	(0.016)	(0.013)	(0.011)	(0.012)
Age	−0.024	−0.023	−0.018	−0.022	−0.009	−0.008	−0.007
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Labor income		−0.760					0.262
		(0.039)					(0.025)
Financial wealth			−0.565				−0.096
			(0.041)				(0.032)
Participation dummy				−0.233		−0.196	−0.198
				(0.006)		(0.003)	(0.004)
DC account balance					−0.666	−0.603	−0.618
					(0.026)	(0.022)	(0.017)
R^2	0.630	0.687	0.740	0.730	0.786	0.855	0.859

To better understand the role of incremental information in the form of additional state variables, Specifications (2) to (5) add one additional state variable at a time to the age variable. All additions significantly improve the regression fit. In Specifications (2) and (3), labor income and financial wealth add 6 and 11 percentage points, respectively, to the R^2. Stock market participation status in Specification (4) adds 10 percentage points, with the estimates suggesting that stock market participants should have 23.3 percentage points less exposure to equity than nonparticipants, a substantial difference. However, the single most influential state variable is the DC account balance. Specification (5) shows that the DC equity share should be reduced by 0.9 percentage points per year as a direct effect of age. The remaining reduction is contingent on the evolution of the DC account balance. In addition to the direct effect, the DC equity share should be reduced by 6.7 percentage points for every SEK 100,000 increase in the account balance. This increase is in turn a function of the contribution to the account (i.e., labor income) and the realized equity return. The R^2 associated with this simple asset allocation rule increases by 16 percentage points relative to Specification (1), which implies that the rule can account for an impressive 78.6% of the variation in the optimal allocation. It is particularly encouraging that the DC account balance is the single best piece of incremental information, as it is directly observable.

Specification (6) reports results on the effects of the rule based on both the DC account balance and stock market participation. The optimal rule can be stated as follows: reduce the DC equity share by 0.8 percentage points every year, reduce the DC equity share by 6.0 percentage points for every SEK 100,000 invested in the account, and reduce the life-cycle path by 19.6 percentage points if the individual is a stock market participant. This rule summarizes the model implications well and accounts for 85.5% of the model's optimal asset allocation rule. The R^2 for Specification (7) reveals that labor income and financial wealth add little on the margin.

E. Welfare Effects

We next analyze the welfare effects of implementing an increasingly customized default design. We also analyze the endogenous change in the population shares of default and opt-out investors.

E.1. Three Default Designs and Three Groups of Default Investors

We gradually increase the customization, starting from the baseline "100-minus-age" allocation. This is our first allocation rule and default investor sample (58.7% of all individuals). Based on the optimal design for them, we obtain the average optimal age-based rule, representing the best purely age-based rule for default investors. The bottom-right panel of Figure 3 plots its glide path. Based on this design, we obtain a second sample of default investors. From this sample we estimate a rule-of-thumb allocation using Specification (6) in Table VI. We implement this rule of thumb and obtain a third sample of default investors. Finally, we report results for the optimal design. For each incremental shift in customization we report the welfare gain relative to the previous design and the share of default investors. We report effects for the sample of investors who stay in the default under the "100-minus-age" allocation unless otherwise noted.[18]

E.2. Responses to the Customization

The first row of Table VII shows how the share of default investors increases as the degree of design customization increases, starting from the "100-minus-age" allocation. Shifting the glide path to the average within the model increases the share by 9.2 percentage points to 67.9%. Shifting the design from the average to the rule of thumb further increases the share of default investors by 7.4 percentage points to 75.3%. Put differently, implementing the rule of thumb induces an endogenous response so that the share of opt-out investors is decreased by 16.6 percentage points.

A central insight is that the groups of opt-out and default investors are endogenously generated, arising in response to a particular default design and

[18] Finding the optimal design for any degree of customization is a fixed-point problem. We present the results of one iteration, as a second iteration yields very similar DC equity shares and a similar rule of thumb.

Table VII

Welfare Analysis and Endogenously Determined Default Investors

The table presents the effects of the gradual implementation of a more customized default fund. The first column corresponds to the initial design, “100-minus-age.” The fourth column corresponds to implementation of the model’s optimal (i.e., fully customized) default allocation. The second and third columns are intermediate allocation steps (i.e., average optimal and rule-of-thumb allocations). The first line reports the share of default investors out of a total population of default plus opt-out investors equal to 11,500. The second line reports the incremental welfare gain in percent during the retirement phase of moving one step toward more customization from the first column. The third line reports the cumulative gain in percent. The welfare gains in lines two and three correspond to investors who are in the default when offered the “100-minus-age” rule. The fourth line reports the corresponding cumulative gain in percent for all investors. To obtain welfare gains expressed as a constant gain throughout the life-cycle, the reported gains should be divided by approximately 29, following the discounting in the Internet Appendix (Section VII). The regressions follow the regression in Table VI with default investors generated under respective default design. The first column is identical to column (6) of Table VI. The simulated data are based on 50 economies, each of which has 11,500 investors who work for 40 years. The number of observations in each column is as follows: 13,492,000; 15,624,000; 17,326,000; and 23,000,000. Labor income, financial wealth, and DC account balance are scaled down by 1,000,000. Standard errors, robust to conditional heteroskedasticity and clustered over economy and individual, are reported in parentheses. Pension income is pension income at age 65 years. For pension income, the samples in all columns are held constant for the default investors under “100-minus-age” (6,746 individuals). The mean is the average over economies and individuals. Equity risk is the standard deviation of the log of average pension income across 50 economies. Inequality is the standard deviation of the log of average pension income across 6,746 individuals.

	“100-Minus-Age”	Average Optimal	Rule of Thumb	Optimal
Share of default investors	0.587	0.679	0.753	1.000
Incremental welfare gain	–	0.3%	0.6%	0.6%
Cumulated welfare gain	–	0.3%	0.9%	1.5%
Cumulated welfare gain (all)	–	0.2%	0.7%	1.6%
Regressions				
Constant	1.347	1.363	1.384	1.411
	(0.011)	(0.015)	(0.018)	(0.022)
Age	−0.008	−0.009	−0.009	−0.010
	(0.001)	(0.001)	(0.001)	(0.001)
Participation dummy	−0.196	−0.199	−0.198	−0.195
	(0.003)	(0.003)	(0.003)	(0.003)
DC account balance	−0.603	−0.564	−0.533	−0.505
	(0.022)	(0.027)	(0.031)	(0.035)
R^2	0.855	0.855	0.853	0.850
Pension income				
Mean	154,880	155,461	158,952	152,281
Equity risk	0.121	0.122	0.127	0.087
Inequality	0.234	0.233	0.194	0.196

institutional setting. Carroll et al. (2009) show how the optimal design depends on the underlying characteristics of the default group (e.g., whether they are procrastinators or whether they lack financial literacy). We have limited ability to explore such differences. We do explore, however, how the optimal default design changes across our samples of default investors arising from different default designs. We find that the default investors are less negatively selected the more customized the default fund is. Considering the life-cycle paths for the suboptimal default designs, labor income peaks at SEK 261,400 under the "100-minus-age" design and at SEK 282,200 under the rule of thumb. Despite these fairly large differences, the discrepancy of the average DC equity share is small—at most three percentage points in mid working life. We view this as quite encouraging, as it suggests that the optimal DC equity share is robust to particular historical (suboptimal) default designs.

E.3. Welfare

We report welfare effects based on ex ante increases in certainty-equivalent consumption (i.e., based on unconditional expectations at age 25). The advantage of this measure is that it trades off increases in returns (i.e., pension income) against increases in risk (in returns and pension income) in a consistent manner. (In contrast, if we maximized the average ex post replacement rate, it would suffice to maximize the allocation to equity.) We compute the gain in certainty-equivalent consumption during retirement. We report the welfare gain measured as the percent increase in certainty-equivalent consumption during retirement, viewed from the perspective of a 25-year-old investor whose consumption remains the same during the working phase. Alternatively, the gain could be measured as an increase during the working and retirement phases. The gain is then smaller by a factor of approximately 29 because of discounting. In the Internet Appendix (Section VII), we describe how to derive this measure from investors' value function.

The second row of Table VII reports the incremental increases in welfare, as the design becomes more customized, for those who stay in the default when offered the "100-minus-age" allocation. Moving from the "100-minus-age" allocation to the average optimal glide path increases investors' welfare by 0.3% on average. This effect is small relative to the effect of moving from the average optimal glide path to the rule of thumb glide path, implying a gain of 0.6%. To put the size of this effect in perspective, we investigate the gain from a shift from the optimal constant equity share (i.e., 50% equity and 50% risk-free bonds in our baseline calibration) to the "100-minus-age" allocation, as life-cycle investing or target-date investing is commonly believed to add value to pension investors. Surprisingly, we find that the gain is a mere 0.1%. Thus, modifying the glide path further toward that of the average optimal is more valuable to investors than is switching from the optimal constant allocation to the "100-minus-age" allocation. Moreover, moving from the average optimal glide path to the rule of thumb is associated with a 1.5 times greater gain than is moving from the optimal constant equity share to the average optimal glide path. This suggests that customization, beyond that related to age, can provide value to pension investors. Finally, moving from the rule of thumb to the true optimal allocation adds an incremental gain of 0.6%. The total effect of moving from the "100-minus-age" allocation to the optimal allocation (the third row in Table VII) is thus 1.5%. This is a sizable gain for this class of incomplete market models. In comparison, Campbell and Cocco (2015) report a 1.1% welfare gain from offering fixed-rate mortgages in high-yield states for one-year bonds.

Unlike many other reforms, customization in our partial equilibrium setting is also Pareto improving: ex ante there are no losers from a better design. We find that the range of the total welfare gain in moving from the "100-minus-age" allocation to the optimal allocation is 0.9% to 2.9%. When we investigate how much individuals who switch from opting out to being default investors gain relative to those who were already default investors, we find that switchers gain only 0.1 percentage points more, which reassures us that the results are not driven by reductions in the cost of opting out (i.e., that fewer individuals pay the cost κ_i^{DC}). Moreover, we check that no default investors abandon the default fund and opt out as customization increases. For completeness, the fourth row of Table VII reports the welfare gain for all investors. This metric takes into account that those who continue to opt out do not benefit from the customization of the rule. It also factors in the gains of switchers.[19] We find that moving from a suboptimal age-based investment rule (e.g., "100-minus-age") to the rule of thumb realizes much (60%) of the potential welfare gain from implementing the optimal design. Furthermore, tailoring the rule precisely to a particular endogenous sample of default investors turns out to be of little importance. The middle panel of Table VII reports the regression results. Across our samples of default investors the rule is quite similar. This similarity further supports our argument that the optimal default design is robust to particular initial suboptimal default offerings.

F. Effects on Pension Income

The optimal design trades off risk against return perfectly. To understand how this affects pension income, the bottom panel of Table VII reports the average pension, equity risk, and inequality for the four designs. The first measure is an (unconditional) average over individuals and economies; the last two measures are standard deviations of log pension income, computed across economies or individuals. Notably, the average pension is little affected by customization, being highest for the rule of thumb and lowest for the optimal design. However, this variation is small compared with the variation in equity risk and inequality. Inequality decreases by 16% and equity risk by 28% in the optimal design. The bottom line is that the optimal default mainly reduces excess equity risk and provides a means to reduce inequality while maintaining the same average pension income.[20]

[19] Notice that, since switchers gain a bit more than those who stay in the default under "100-minus-age," the welfare gain in the fourth line of Table VII is somewhat different from the product of the "Share of default" and "Cumulated welfare gain."

[20] Our proposed linear rule of thumb is a little coarse in terms of managing equity risk. It offers the most equity risk, so the average pension is high under its implementation. This is because linearity implies that the equity exposure late in life exceeds that of the optimal design. It is easy to formulate an extended rule that corrects this and provides an average pension, equity risk, and

G. Robustness

We investigate how our main results vary with alternative assumptions in our model. Importantly, we recalibrate our model to these assumptions to maintain the best possible fit for the targeted moments in the data. Below, we briefly describe the main findings. We report details on the alternative calibrations, targeted moments, and main results in the Internet Appendix (Sections VIII and IX).

We find that our main results hold both qualitatively and quantitatively throughout the exercises. In particular, the welfare gain, the fraction of it that can be achieved using either the optimal average allocation or the rule of thumb, and the change in the fraction of investors who opt out are all similar to those in the benchmark case.

G.1. Alternative Processes for Equity Returns and Model Misspecification

A common choice for the equity risk premium in portfolio choice models is 4%, as in our baseline calibration. Here, we investigate whether our results are sensitive to its magnitude by decreasing it to 2%. Note that a lower equity premium tends to come with lower risk aversion, so this test is also a robustness check of the importance of high risk aversion. That the results would be robust to this change is not obvious. On the one hand, equity and bonds become more similar in terms of expected return, so the asset allocation decision becomes less potent. On the other hand, it may be valuable to extract even a small equity premium in states in which risk-averse individuals can tolerate it. Our main welfare results are insensitive to this change. The welfare gain associated with a shift from the "100-minus-age" allocation to the optimal allocation is 1.6%, 63% of which can be attained by the rule of thumb. The opt-out rates are therefore unaffected.

It is well documented that equity returns are left skewed. In life-cycle portfolio choice models, this feature is implemented as a small probability of a disastrous equity return (see, for example, Alan (2012), Fagereng, Gottlieb, and Guiso (2017)). We follow the approach of Judd, Maliar, and Maliar (2011) and modify the equity return distribution so that an annual return of –41% (the expected return minus two and a half standard deviations) is drawn with a 2% probability. Importantly, this disaster shock feeds into labor income through (6) and (8). From this exercise, we conclude that our main results are robust. The total welfare effect is still 1.5% and the rule of thumb accounts for 60% of the total welfare gain.

We also consider the effects of model misspecification along these dimensions, analogous to Michaelides and Zhang (2017). We implement the benchmark estimates for the rule of thumb in a model using either of the above alternative stochastic processes. Even when feeding in such a misspecified rule of thumb, there are no meaningful differences.

inequality that lie between the average optimal and optimal designs. Designers will thus need to trade off simplicity against accuracy.

G.2. Suboptimal Portfolio Choice Outside the Pension System

In our main analysis, stock market participants allocate their portfolio optimally outside of the pension system. We view this as a natural baseline, as the implementation of systematic suboptimal behavior outside the pension system would increase the value of a well-designed default allocation inside the pension system. However, empirical evidence suggests that investors lack knowledge of different asset classes' risk-return properties and consequently do not have sufficient information to form their portfolios (see, for example, Carroll et al. (2009)). Empirical evidence also suggests that individuals make savings and allocation choices in one account independent of what is happening in other accounts (Choi, Laibson, and Madrian (2009), Card and Ransom (2011), Chetty et al. (2014)). We therefore analyze whether our results are affected by individuals making mistakes outside the pension system. We consider two kinds of mistakes.

First, we assume that individuals participating in the stock market hold a constant fraction of their financial wealth in equity. We let this fraction equal the mean in the data (43.2%). Under this behavior, the value of a customized default in the DC account increases. Moving from a "100-minus-age" allocation to the optimal design implies a welfare gain of 2.1%. Implementing the rule of thumb captures half of this gain.

Second, we assume that individuals participating in the stock market make random allocation mistakes. That is, unlike in the first analysis, there is variation in the cross-section. We implement this as an exogenous time-invariant state variable. Individuals are predestined to hold one of five equity shares if they choose to become stock market participants. The five values correspond to the mean of each quintile of the cross-sectional distribution. That individuals are aware of their tendency to make mistakes is consistent with the argumentation of Calvet, Campbell, and Sodini (2007). We assume that the designer of the default pension fund cannot observe these five types when implementing the rule of thumb. In this exercise, the value of the optimal default compared to "100-minus-age" is 2.3%. Implementing the rule of thumb again captures half of this gain. Hence, even with unobserved cross-sectional variation in suboptimal equity shares, the rule of thumb adds value.

The results illustrate that an individualized default can compensate for systematic portfolio choice mistakes outside the pension system.

G.3. Moderating the Attractiveness of Equities among the Young

Figure 1 shows a difference in the life-cycle profile of the conditional equity share between the data and the model. In the data, the profile is flat; in the model, it slopes downward and the difference between the maximum and minimum points during the working phase is 76 percentage points. This follows from the bond-like property of labor income. There does not seem to be a commonly agreed solution to this problem in the literature.

Benzoni, Collin-Defresne, and Goldstein (2007) let labor income and dividends be cointegrated, making equity more risky for young investors and even generating an upward slope in the equity share. Relatedly, Storesletten, Telmer, and Yaron (2007) introduce cyclical income risk and Huggett and Kaplan (2016) introduce left skewness in labor income together with cyclical income risk. All of these models introduce features that make labor income more risky.

As a complement to assuming outright suboptimal behavior, we also make the stream of labor income more equity-like. We can preserve a substantial stock market participation rate outside the DC account if the correlation between labor income growth and equity returns is smaller than 0.30. With a correlation of 0.22, the difference between the maximum and minimum points of the conditional equity share during the working phase declines from 76 to 44 percentage points. The main results regarding welfare and the share of default investors under the rule of thumb remain intact.

To stress the model further, we combine the high correlation with the left skewness in stock market returns (we increase the probability to 5%). We can then further reduce the difference between the maximum and minimum conditional equity share from 44 to 29 percentage points. Again, the welfare gains from introducing the optimal design or the rule of thumb are similar.

G.4. Real Estate Wealth

We highlight the importance of real estate in our empirical analysis. Renters are less likely to be active investors than are real estate owners. They are also less likely to be stock market participants. Furthermore, for most households real estate wealth minus debt (henceforth "home equity") is as great as their financial wealth. Net worth is thus almost as unevenly distributed among investors as is financial wealth.

We consider four robustness exercises that account for heterogeneity in real estate, each involving a complete recalibration of the model to alternative data moments. In the first two exercises, we target renters and real estate owners separately. Renters have a lower life-cycle trend in labor income. In this exercise, the welfare gain from a customized default design is 1.4% (i.e., slightly smaller than for the full sample), whereas the share captured by the rule of thumb remains essentially unchanged. Real estate owners, in contrast, have a higher life-cycle trend in labor income. In this exercise, the welfare gain from a customized default design is 1.7% (i.e., somewhat greater than for the full sample). The share captured by the rule of thumb is about the same.

We next consider two exercises in which renters and real estate owners are considered together. We focus on the heterogeneity in net worth. Whether net worth is an important factor depends on how accessible home equity is to investors during retirement. We conjecture that the default design could be more aggressive if it were easy for investors to consume out of home equity, as it would then offer a margin of self-insurance. Conversely, if investors are rooted in their houses and/or face large transaction costs, home equity may affect the optimal DC asset allocation less.

To avoid additional state variables, we make extreme assumptions as to the properties of the real estate and mortgage markets. First, we assume that house price growth is spanned by the risk-free asset and the equity market. Second, we assume that a mortgage equals a negative position in the risk-free asset. Third, we assume that transactions are costless. We next make different assumptions about the riskiness of housing and moderate the calibration targets accordingly. In the third exercise, we assume that real estate wealth is risk-free. Stock market participation is thus unchanged relative to the main calibration but the conditional equity share is lower. Importantly, the calibration now targets a wealth-to-income ratio of 2.63 instead of 0.92, making the DC account less critical in sustaining the retirement phase. This is manifested as a welfare gain of 1.1% (i.e., lower than in the baseline analysis). However, the share achieved by the rule of thumb remains intact. In the fourth exercise, we let the risk premium in the housing market be in line with the literature (see, for example, Cocco (2005), Yao and Zhang (2005)). We assume that house price growth carries a risk premium of 1%. Given that the loan-to-value ratio among investors is approximately 0.5, this implies a risk premium on home equity of 2%. We therefore model home equity as 50% risk-free and 50% equity. In this exercise, we redefine both participation and the conditional equity share in the calibration. The welfare gain is 1.2%, again lower than in the baseline analysis, but the rule of thumb still accounts for half of the full gain.

VI. Concluding Remarks

We use a life-cycle consumption-savings model with risky labor income and a DC pension plan to examine the effects of different equity exposures in the default fund.

Relative to a common age-based allocation rule for equity exposure, that is, "100-minus-age," the average ex ante welfare gain from implementing the optimal asset allocation equals 1.5% during the retirement phase. In addition to the investor's age, the optimal asset allocation rule relies heavily on the investor's pension account balance and stock market participation status outside the pension plan. Much of the welfare gain is attainable by implementing a simple rule of thumb conditioned on these three observable characteristics. According to the model, conditioning on the investor's pension account balance and stock market participation status is as important as conditioning on the investor's age. Our model suggests that 40% of active pension investors who opt out when offered a default fund that invests according to "100-minus-age" would rather choose the default fund if it were invested according to our proposed rule of thumb.

We believe that asset allocation rules are a promising avenue for achieving cost-effective mass customization (see Bodie, Detemple, and Rindisbacher (2009) for a discussion of the costs of individualized allocations). The pension account balance is particularly useful, as this information is readily available to the pension plan designer. Hence, we encourage pension agencies and plan sponsors to study the legal and political aspects of designing a default fund based not only on age but also on other observable characteristics. A practical implementation may take the form of a robo-advisor.

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REFERENCES

Abel, Andrew B., 2001, The effects of investing social security funds in the stock market when fixed costs prevent some households from holding stocks, *American Economic Review* 91, 128–148.

Alan, Sule, 2006, Entry costs and stock market participation over the life cycle, *Review of Economic Dynamics* 9, 588–611.

Alan, Sule, 2012, Do disaster expectations explain household portfolios? *Quantitative Economics* 3, 1–28.

Ameriks, John, and Stephen P. Zeldes, 2004, How do household portfolio shares vary with age? Working paper, Columbia University.

Benartzi, Shlomo, and Richard H. Thaler, 2001, Naive diversification strategies in defined contribution saving plans, *American Economic Review* 91, 79–98.

Benartzi, Shlomo, and Richard H. Thaler, 2007, Heuristics and biases in retirement savings behavior, *Journal of Economic Perspectives* 21, 81–104.

Benzoni, Luca, Pierre Collin-Dufresne, and Robert S. Goldstein, 2007, Portfolio choice over the life-cycle when the stock and labor markets are cointegrated, *Journal of Finance* 62, 2123–2167.

Bergstresser, Daniel, and James Poterba, 2004, Asset allocation and asset location: Household evidence from the survey of consumer finances, *Journal of Public Economics* 88, 1893–1915.

Bodie, Zvi, Jérôme Detemple, and Marcel Rindisbacher, 2009, Life-cycle finance and the design of pension plans, *Annual Review of Financial Economics* 1, 249–260.

Bodie, Zvi, Robert C. Merton, and William F. Samuelson, 1992, Labor supply flexibility and portfolio choice in a life cycle model, *Journal of Economic Dynamics & Control* 16, 427–449.

Calvet, Laurent E., John Y. Campbell, and Paolo Sodini, 2007, Down or out: Assessing the welfare costs of household investment mistakes, *Journal of Political Economy* 115, 707–747.

Calvet, Laurent E., John Y. Campbell, and Paolo Sodini, 2009, Fight or flight? Portfolio rebalancing by individual investors, *Quarterly Journal of Economics* 124, 301–348.

Campanale, Claudio, Carolina Fugazza, and Francisco Gomes, 2014, Life-cycle portfolio choice with liquid and illiquid financial assets, *Journal of Monetary Economics* 71, 67–83.

Campbell, John Y., 2016, Restoring rational choice: The challenge of consumer financial regulation, *American Economic Review, Papers & Proceedings* 106, 1–30.

Campbell, John Y., and João F. Cocco, 2015, A model of mortgage default, *Journal of Finance* 70, 1495–1554.

Card, David, and Michael Ransom, 2011, Pension plan characteristics and framing effects in employee savings behavior, *Review of Economics and Statistics* 93, 228–243.

Carlsson, Evert, Karl Erlandzon, and Jonas Gustavsson, 2008, A tale of two systems: Winners and losers when moving from defined benefit to defined contribution pensions, *Mathematical Methods in Economics and Finance* 3, 17–39.

Carroll, Gabriel D., James J. Choi, David Laibson, Brigitte C. Madrian, and Andrew Metrick, 2009, Optimal defaults and active decisions, *Quarterly Journal of Economics* 124, 1639–1674.

Chetty, Raj, John N. Friedman, Søren Leth-Petersen, Torben Heien Nielsen, and Tore Olsen, 2014, Active vs. passive decisions and crowd-out in retirement savings accounts: Evidence from Denmark, *Quarterly Journal of Economics* 129, 1141–1219.

Chetty, Raj, László Sándor, and Adam Szeidl, 2017, The effect of housing on portfolio choice, *Journal of Finance* 72, 1171–1212.

Choi, James, David Laibson, and Brigitte C. Madrian, 2009, Mental accounting in portfolio choice: Evidence from a flypaper effect, *American Economic Review* 99, 2085–2099.

Choi, James J., David Laibson, and Brigitte C. Madrian, 2010, Why does the law of one price fail? An experiment on index mutual funds, *Review of Financial Studies* 23, 1405–1432.

Choi, James J., David Laibson, Brigitte C. Madrian, and Andrew Metrick, 2003, Optimal defaults, *American Economic Review: Papers & Proceedings* 93, 180–185.

Christelis, Dimitris, Dimitris Georgarakos, and Michael Haliassos, 2011, Stockholding: Participation, location, and spillovers, *Journal of Banking and Finance* 35, 1918–1930.

Cocco, João F., 2005, Portfolio choice in the presence of housing, *Review of Financial Studies* 18, 535–567.

Cocco, João F., Francisco J. Gomes, and Pascal J. Maenhout, 2005, Consumption and portfolio choice over the life cycle, *Review of Financial Studies* 18, 491–533.

Cocco, João F., and Paula Lopes, 2011, Defined benefit or defined contribution? A study of pension choices, *Journal of Risk and Insurance* 78, 931–960.

Cronqvist, Henrik, and Richard H. Thaler, 2004, Design choices in privatized social-security systems: Learning from the Swedish experience, *American Economic Review: Papers & Proceedings* 94, 424–428.

Dahlquist, Magnus, José Vicente Martinez, and Paul Söderlind, 2017, Individual investor activity and performance, *Review of Financial Studies* 30, 866–899.

Dammon, Robert M., Chester C. Spatt, and Harold H. Zhang, 2004, Optimal asset location and allocation with taxable and tax-deferred investing, *Journal of Finance* 59, 999–1037.

Epstein, Larry G., and Stanley E. Zin, 1989, Substitution, risk aversion, and the temporal behavior of consumption and asset returns: A theoretical framework, *Econometrica* 57, 937–969.

Fagereng, Andreas, Charles Gottlieb, and Luigi Guiso, 2017, Asset market participation and portfolio choice over the life-cycle, *Journal of Finance* 72, 705–750.

Fischer, Marcel, Holger Kraft, and Claus Munk, 2013, Asset allocation over the life cycle: How much do taxes matter? *Journal of Economic Dynamics & Control* 37, 2217–2240.

French, Eric, and John Bailey Jones, 2011, The effects of health insurance and self-insurance on retirement behavior, *Econometrica* 79, 693–732.

Gomes, Francisco J., Laurence J. Kotlikoff, and Luis M. Viceira, 2008, Optimal life-cycle investing with flexible labor supply: A welfare analysis of life-cycle funds, *American Economic Review: Papers & Proceedings* 98, 297–303.

Gomes, Francisco, and Alexander Michaelides, 2005, Optimal life-cycle asset allocation: Understanding the empirical evidence, *Journal of Finance* 60, 869–904.

Gomes, Francisco, and Alexander Michaelides, 2008, Asset pricing with limited risk sharing and heterogeneous agents, *Review of Financial Studies* 21, 415–449.

Gomes, Francisco, Alexander Michaelides, and Valery Polkovnichenko, 2009, Optimal savings with taxable and tax-deferred accounts, *Review of Economic Dynamics* 12, 718–735.

Huberman, Gur, and Wei Jiang, 2006, Offering versus choice in 401(k) plans: Equity exposure and number of funds, *Journal of Finance* 61, 763–801.

Huggett, Mark, and Greg Kaplan, 2016, How large is the stock component of human capital? *Review of Economic Dynamics* 22, 21–51.

Judd, Kenneth L., Lilia Maliar, and Serguei Maliar, 2011, Numerically stable and accurate stochastic simulation approaches for solving dynamic economic models, *Quantitative Economics* 2, 173–210.

Koijen, Ralph S.J., Stijn Van Nieuwerburgh, and Roine Vestman, 2015, Judging the quality of survey data by comparison with "truth" as measured by administrative records: Evidence from Sweden, in Christopher Carroll, Thomas Crossley, and John Sabelhaus, eds.: *Improving the Measurement of Consumer Expenditures* (University of Chicago Press, Chicago).

Lucas, Deborah J., and Stephen P. Zeldes, 2009, How should public pension plans invest? *American Economic Review: Papers & Proceedings* 99, 527–532.

Lusardi, Annamaria, and Olivia S. Mitchell, 2014, The economic importance of financial literacy: Theory and evidence, *Journal of Economic Literature* 52, 5–44.

Madrian, Brigitte C., and Dennis F. Shea, 2001, The power of suggestion: Inertia in 401(k) participation and savings behavior, *Quarterly Journal of Economics* 116, 1149–1187.

Merton, Robert C., 1971, Optimal consumption and portfolio rules in a continuous-time model, *Journal of Economic Theory* 3, 373–413.

Michaelides, Alexander, and Yuxin Zhang, 2017, Stock market mean reversion and portfolio choice over the life cycle, *Journal of Financial and Quantitative Analysis* 52, 1183–1209.

Poterba, James, Joshua Rauh, Steven Venti, and David Wise, 2007, Defined contribution plans, defined benefit plans, and the accumulation of retirement wealth, *Journal of Public Economics* 91, 2062–2086.

Poterba, James M., 2014, Retirement security in an aging population, *American Economic Review: Papers & Proceedings* 104, 1–30.

Shiller, Robert J., 2006, Life-cycle personal accounts proposal for Social Security: An evaluation of President Bush's proposal, *Journal of Policy Modeling* 28, 427–444.

Sialm, Clemens, Laura T. Starks, and Hanjiang Zhang, 2015, Defined contribution pension plans: Sticky or discerning money? *Journal of Finance* 70, 805–838.

Storesletten, Kjetil, Chris I. Telmer, and Amir Yaron, 2007, Asset pricing with idiosyncratic risk and overlapping generations, *Review of Economic Dynamics* 10, 519–548.

Vestman, Roine, 2017, Limited stock market participation among renters and home owners, Review of Financial Studies (forthcoming).

Viceira, Luis M., 2001, Optimal portfolio choice for long-horizon investors with nontradable labor income, *Journal of Finance* 56, 433–470.

Vissing-Jørgensen, Annette, 2002, Towards an explanation of household portfolio choice heterogeneity: Nonfinancial income and participation cost structures, NBER working paper.

Yao, Rui, and Harold H. Zhang, 2005, Optimal consumption and portfolio choices with risky housing and borrowing constraints, *Review of Financial Studies* 18, 197–239.

Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's website:

Appendix S1: Internet Appendix.
Replication Code.
Model Code.