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Optimal Defined Contribution Pension Plans: One-Size Does Not Fit All*

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PRELIMINARY AND INCOMPLETE

Abstract

We build a quantitative model to study the optimal design of a defined contribution pension plan. We find that commonplace designs, with a fixed contribution rate for all individuals at all times, are unnecessarily rigid. We propose a design where the contribution rate is a function of individuals' age, income, and stock market participation status. Compared to a typical rigid rule for the replacement rate, our rule leads to the same average replacement rate but less cross-sectional dispersion. The average welfare gain is three percent.

JEL classification: D91, E21, G11, H55.
Keywords: Age-based investing, life-cycle model, pension plan design.

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1 Introduction

Developed countries are gradually undertaking reforms that separate pension systems from the fiscal budget. A consequence of this is that more of the economic risks are borne by workers rather than employers or the government. A typical feature of such reforms is to rely more on defined contribution (DC) pension plans. OECD (2017) reports that 32 out of 34 member countries have mandatory or quasi-mandatory second-tier pension provision for workers. Fifteen of these member countries have DC pension plan schemes. However, there is a great deal of dispersion across the systems. The mandatory DC contribution rate varies between 2% and 15%, suggesting that there is arbitrariness in the systems' design. Furthermore, some design features of the DC pension plans are at odds with optimal behavior according to the basic life-cycle consumption-savings model. Two such features are the constant contribution rate out of income and the inability to halt contributions to the account in the presence of transitory shocks. In this sense, existing DC pension plans appear to be unnessarily rigid.

The purpose of this paper is to investigate the welfare gains of offering flexibility in DC pension plans beyond existing designs. We set up a life-cycle consumption-savings model where replacement rates are a function of the design of a first and second tier pension system. The first tier is a safe government-mandated savings account and guarantees a replacement rate of around 50% out labor income. The second tier pension system consists of a DC pension plan, which could be government-mandated or quasi-mandatory. Our calibration is based on Swedish micro data and the Swedish institutional setting, which is often considered a model for other countries. We report two main findings.

First, we decompose the savings motive of individuals. We find that the precautionary savings motive is modest, even with a high coefficient of risk aversion and in the presence of a rich shock structure. Rather, the main motive for accumulating financial wealth is to sustain consumption in retirement. Furthermore, the optimal contribution rates vary tremendously with age and other individual characteristics. Optimal DC contribution rates are zero, or close to zero, early in life while they could be twenty percent later on. This is in contrast to the Swedish setting with a contribution rate fixed at seven percent. We also find that contribution rates should ideally be tailored to individual characteristics, in particular labor income and stock market exposure outside the pension system.

Second, we consider a design of the DC pension plan which is closer to optimal behavior in a life-cycle consumption-savings model. We propose a rule of thumb for the contribution rate that takes into account individual state variables and embeds a great deal of flexibility. We demonstrate that while preserving replacement rates of the more rigid design, our rule produces outcomes that are much closer to the optimal. The welfare gains of the more flexible design is on average 3% while replacement rates are equal on average and display less cross-sectional dispersion. Compared to the rigid design, only individuals that are 3.6 standard deviations, or more, below the average gain lose.

Our analysis relates to several strands of the literature on pension plan design and savings rates of individuals and households. First, there is a ongoing debate about auto-enrollment into pension plans and auto-escalation of contribution rates, in particular for the U.S. where designs of DC pension plans vary more (see Beshears, Choi, Laibson, and Madrian (2018) for a discussion of defaults). Our results suggest that designing defaults that involve auto enrollment and automatic adjustments of the contributions depending on individual circumstances, as our proposed rule of thumb, would cause little harm while simultaneously provide a strong nudge to save, as is typical for default options. Second, our emphasis on flexibility is in line with for instance Beshears, Choi, Iwry, John, Laibson, and Madrian (2019) who discuss different designs of savings accounts that would enable individuals to build emergency savings and self-insurance to the kind of expense shocks or transitory income shocks that we consider. Third, our model can also be viewed as an extension of previous models. Sandris Larsen and Munk (2019) is perhaps most similar to our study. They study how to design optimal contribution rates given that pension plans are mandatory. Our model is however quantitatively richer in that we allow for a greater deal of heterogeneity and transitory income shocks. Pries (2007) uses a quantitative life-cycle model to study labor supply responses and welfare effects associated with reform of U.S. Social Security to a system with individual accounts with age-dependent contribution rates.

The paper proceeds as follows. Section 2 provides an overview of the Swedish pension system. Section 3 presents our life-cycle model and its calibration. Section 4 examines the economic forces that determine individuals' savings motive. Section 5 presents the implications of a flexible design of the contribution rate into the DC pension plan. Finally, Section 6 concludes.

2 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.

The public pension system was reformed in 2000.[1] It has two major components referred to as 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 income, though the income is capped (in 2014 the cap was SEK 426,750, or approximately USD 62,200).[2] The return on the contribution equals the growth rate of aggregate labor income 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

[1] 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.

[2] In 2014 the SEK/USD exchange was around seven. During our sample period, the exchange rate has fluctuated between six and ten SEK per USD. We henceforth report numbers in SEK.

to fund current pension payments as in a traditional pay-as-you-go system. It is worth mentioning that the notional income-based pension is also DC, but to avoid confusion we simply 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 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, e.g., Dahlquist et al., 2015). A government agency manages a default fund for individuals who 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 the time of retirement, the savings in the income-based pension and the premium pension are transformed into actuarially fair life-long 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 1980, the rules are fairly homogeneous, regardless of education and occupation. The contribution is 4.5% of an individual's income (capped as above) and it goes into a designated individual DC account. For the part of the income that exceeds the cap, the contribution rate is greater in order to achieve a high replacement rate even for high-income individuals. 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.

3 The model

We set up a life-cycle model for the economic situation of a Swedish individual. The model is an extension of Dahlquist, Setty, and Vestman (2018) which in turn builds on Viceira (2001), Cocco et al. (2005), and Gomes and Michaelides (2005). It includes risky labor income, a consumption–savings choice, and a portfolio choice. We augment the model with a pension system in which individuals save in two pension accounts, from which their pension is received as annuities. One of the accounts belongs to the first pillar of the pension system and is pay-as-you-go but with an individual notional balance. The other account is a standard defined contribution pension account where contributions are either rigid or flexible. It represents the second pillar of the pension system.[3]

Next we describe the model's building blocks.

3.1 Demographics

We follow individuals from age 25 until the end of their lives.[4] The end of life occurs at the latest at age 100, but could occur before as individuals face an age-specific survival rate, ϕ_t. The life cycle is split into a working, or accumulation, phase and a retirement phase. From the ages of 25 to 64 years, individuals work and receive labor income exogenously. They retire at age 65.

[3] Our model relates to Gomes et al. (2009), who consider portfolio choice in the presence of tax-deferred retirement accounts, and to Campanale et al. (2014), who consider a model in which stocks are subject to transaction costs, making them less liquid.

[4] We choose age 25 as the start of the working phase, as Swedish workers do not fully qualify for occupational pension plans before that age.

3.2 Preferences

The individuals have Epstein and Zin (1989) preferences over a single consumption good. At age t, each individual maximizes the following:

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

$$U_T = c_T, \tag{2}$$

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

3.3 Labor income

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

$$y_{it} = g_t + z_{it}, \tag{3}$$

$$z_{it} = z_{it-1} + \eta_{it} + \theta\varepsilon_t, \tag{4}$$

where $y_{it} = \ln(Y_{it})$. The first component, g_t, is a hump-shaped life-cycle trend. The second component, z_{it}, is the permanent labor income component. It has an idiosyncratic shock, η_{it}, which is distributed $\mathrm{N}\left(-\sigma_\eta^2/2, \sigma_\eta^2\right)$, 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 the labor income and the stock return. We allow for heterogeneity in income as early as age 25 by letting the initial persistent shock, z_{i25}, be distributed $\mathrm{N}(-\sigma_z^2/2, \sigma_z^2)$.

During the retirement phase (from age 65 and onwards), the individual has no labor income.[5] Pension is often modeled as a deterministic replacement rate relative to the labor income just before retirement.[6] However, in our model, the replacement rate is endogenously determined. The individual relies entirely on annuity payments from savings accounts. Later we discuss these accounts in detail.

3.4 Asset returns

The gross return on the stock market, R_{t+1}, develops according to the following log-normal process:

$$\ln(R_{t+1}) = \ln(R_f) + \mu + \varepsilon_{t+1}, \tag{5}$$

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 (4), and that the correlation between stock returns and labor income is governed by the weight θ.

3.5 Three accounts for financial wealth

An individual has three financial savings accounts: (i) a liquid account outside the pension system (which we simply refer 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 provides the basis for the pension, is income based and evolves at the rate of the risk-free bond. The DC account is also income based but the investor can choose how to allocate between bonds and stocks; it corresponds to the default fund we wish to design.

[5]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 et al. (1992) and Gomes et al. (2008).

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

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 the retirement phase. Importantly, the two pension accounts include insurance against longevity risk.

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 $\mathrm{N}(\mu_A - \sigma_A^2/2, \sigma_A^2)$. In each subsequent year, the individual can freely access the 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:

$$A_{it} \geq 0, \tag{6}$$

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

$$\alpha_{it} \in [0, 1]. \tag{7}$$

Taken together, (6) and (7) imply that individuals cannot borrow at the risk-free rate and that they cannot short the stock market or take leveraged positions in it.

3.6 Stock market participation costs and investor types

To enter the stock market outside the pension system, the individual must pay a one-time participation cost, κ_i. (The financial wealth and the decision to invest in the stock market are described later.) A one-time entry cost is common in portfolio-choice models (see, e.g., Alan, 2006; Gomes and Michaelides, 2005, 2008).

The state variable, I_{it}, tracks whether stock market entry has occurred between age 25 and age t; its initial value is zero (i.e., $I_{i25} = 0$). The law of motion for I_{it} is given by:

$$I_{it} = \begin{cases} 1 \text{ if } I_{it-1} = 1 \text{ or } \alpha_{it} > 0 \\ 0 \text{ otherwise} \end{cases} \tag{8}$$

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

A new feature of our model is that we allow for different costs for different investors. We assume a uniform distribution of the cost:

$$\kappa_i \quad \sim \quad U(\underline{\kappa}, \bar{\kappa}), \tag{9}$$

where $\underline{\kappa}$ and $\bar{\kappa}$ denote the lowest and highest costs among all investors, respectively. We justify the dispersion in cost with reference to the documented heterogeneity in financial literacy and financial sophistication (see Lusardi and Mitchell, 2014, for an overview). By introducing a cost distribution, we can replicate the fairly flat life-cycle participation profile in the data.[7] On average, low-cost investors will enter early in life whereas high-cost investors will enter later or never at all. With a sufficiently low value of $\underline{\kappa}$, some low-cost investors will enter immediately. At the end of life, more high-cost than low-cost investors will remain non-participants. For simplicity, we assume that the cost is independent of other characteristics.

[7] Fagereng et al. (2015) present an alternative set-up to account for the empirical life-cycle profiles on portfolio choice. Their set-up involves a per-period cost and a loss probability on equity investments.

The first pillar of the pension system

The first pillar of the pension system is a notional account. Its balance evolves as follows during the working phase:

$$N_{it+1} = (N_{it} + \lambda^{\mathrm{N}} \min\{Y_{it}, \overline{Y}\})R_f, \tag{10}$$

where λ^{N} is the contribution rate for the notional account. Note that the ceiling on the contributions to the DC and notional accounts captures the progressive feature of the pension system.

The second pillar of the pension system

The second pillar of the pension system is a defined contribution pension account with a balance B_{it}. During the working phase, the contribution rate equals $\lambda_{it} \geq 0$. This is the central parameter of our analysis. Going forward, we will label a pension system for which λ_{it} is a positive constant independent of age and and individual characteristics (i.e., $\lambda_{it} = \lambda > 0$) as a rigid pension system. Before retirement ($t \leq 64$), the law of motion for the DC account balance is:

$$B_{it+1} = (B_{it} + \lambda_{it} Y_{it}) R^B_{t+1}. \tag{11}$$

If λ_{it} is zero then individuals need to rely entirely on the first pillar and their liquid financial wealth, A_{it}, to support themselves in retirement.

Annuitization of the pension accounts

Upon retirement at age 65, the DC account and the notional account are converted into two actuarially fair life-long annuities. They insure against longevity risk through within-cohort transfers from individuals who die to survivors. The notional account provides a fixed annuity with a guaranteed minimum. If the balance of the account is lower than is required to meet the guaranteed level at age 65, we let the individual receive 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 the equity exposure as well as realized returns. In expectation, the individual will receive a constant payment each year. The conversion from account balances to annuity payments are functions denoted by $h^B(.)$ and $h^N(.)$. They take the respective balance as argument.

3.6.1 Budget constraint and laws of motions

The budget constraint at all stages in life is the same one and independent of the design of λ_{it}:

$$C_{it} + A_{it} + \kappa_i(I_{it} - I_{it-1}) = X_{it}. \tag{12}$$

where X_{it} denotes (liquid) cash-in-hand. The law of motion for X_{it} is:

$$X_{it+1} = \hat{Y}_{it+1} + A_{it}R^a_{t+1} \tag{13}$$

$$\hat{Y}_{it+1} = \begin{cases} Y_{it+1}\text{exp}(\omega_{it+1}) - \lambda_{it+1}Y_{it+1} & \text{if } t < 64 \\ h^B(B_{it+1}) + h^N(N_{it+1}) & \text{otherwise} \end{cases} \tag{14}$$

where ω_{it+1} is an idiosyncratic expense shock distributed $\text{N}(-\sigma^2_\omega/2, \sigma^2_\omega)$. The law of motion for B_{it} after retirement ($t > 64$) is given by:

$$B_{it+1} = (B_{it} - h^B(B_{it}))R^B_{t+1} \tag{15}$$

and similarly for N_{it}.

3.7 The individual's problem

Next we describe the individual's problem. To simplify the notation, we suppress the subscript i. Let $V_t\left(X_t, B_t, z_t, \kappa, I_t\right)$ be the value of an individual of age t with cash in hand X_t, DC account balance B_t, a persistent income component z_t, cost κ, and stock market participation experience I_t.

The following describes the individual's problem.

The participant's problem

An individual who has already entered the stock market solves the following problem:

$$\begin{aligned} V_t\left(X_t, B_t, z_t, \kappa, 1\right) &= \max_{A_t,\alpha_t}\left\{\left(\left(X_t - A_t\right)^{1-\rho} + \beta\phi_t\mathcal{R}_t\left(V_{t+1}\left(X_{t+1}, B_{t+1}, z_{t+1}, \kappa, 1\right)\right)^{1-\rho}\right)^{\frac{1}{1-\rho}}\right\} \\ & \text{subject to equations (3)–(15).} \end{aligned}$$

The entrant's problem

Let $V_t^+\left(X_t, B_t, z_t, \kappa, 0\right)$ be the value for an individual with no previous stock market participation experience who decides to participate at t. This value can be formulated as:

$$\begin{aligned} V_t^+\left(X_t, B_t, z_t, \kappa, 0\right) &= \max_{A_t,\alpha_t}\left\{\left(\left(X_t - A_t - \kappa\right)^{1-\rho} + \beta\phi_t\mathcal{R}_t\left(V_{t+1}\left(X_{t+1}, B_{t+1}, z_{t+1}, \kappa, 1\right)\right)^{1-\rho}\right)^{\frac{1}{1-\rho}}\right\} \\ & \text{subject to equations (3)–(15).} \end{aligned}$$

The non-participant's problem

Let $V_t^-\left(X_t, B_t, z_t, \kappa, 0\right)$ be the value for an individual with no previous stock market participation experience who decides not to participate at t. This value can be formulated as:

$$\begin{aligned} V_t^-\left(X_t, B_t, z_t, \kappa, 0\right) &= \max_{A_t}\left\{\left(\left(X_t - A_t\right)^{1-\rho} + \beta\phi_t\mathcal{R}_t\left(V_{t+1}\left(X_{t+1}, B_{t+1}, z_{t+1}, \kappa, 0\right)\right)^{1-\rho}\right)^{\frac{1}{1-\rho}}\right\} \\ & \text{subject to equations (3)–(15).} \end{aligned}$$

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

Optimal stock market entry

Given the entrant's and non-participant's problems, the optimal stock market entry is given by:

$$V_t(X_t, B_t, z_t, \kappa, 0) = \max\left\{V_t^+(X_t, B_t, z_t, \kappa, 0), V_t^-(X_t, B_t, z_t, \kappa, 0)\right\}.$$

3.8 Calibration

In this section we describe our calibration strategy. Table 1 reports the values of key parameters. Most parameters are set either according to the existing literature or to match Swedish institutional details; those parameters can be said to be set exogenously. Four parameters are set to match the data as well as possible; those parameters can be said to be determined endogenously.

Exogenous parameters

There are six sets of exogenous parameters.

First, we set the elasticity of intertemporal substitution to 0.5, which is a common value in life-cycle models of portfolio choice (see, e.g., Gomes and Michaelides, 2005).

Second, we set the equity premium to 4% and the standard deviation of the stock market return to 18%. These choices are in the range of commonly used parameter values in the literature. We set the simple risk-free rate to zero, which in other calibrations is often set to 1–2%. We argue that this is correct in our model as labor income does not include economic growth. Thus, we deflate the account returns by the expected growth to obtain coherent replacement rates. As replacement rates in our model are a function of returns, rather than a function of final labor income, this choice is more important to the present model than to previous models. Simulations of the labor income process and contributions to the pension accounts validate our strategy. These simulations indicate that replacement rates at age 65 relative to labor income at age 64 are coherent with Swedish

Pensions Agency forecasts.

Third, we set labor income according to Swedish data. The level of the income profile (g_t) is first set to match gross labor income. Then the profile is adjusted further to account for the fact that gross labor income in the data is after deductions of DC plan contributions. Typical contribution rates are 7% – the sum the premium pension account with a contribution rate of 2.5% and the occupational pension account with a typical contribution rate of 4.5%.[8] We therefore scale up the income profile by a factor of 1.07. Following Carroll and Samwick (1997), we estimate the riskiness of labor income. To abstract from other transfers of the welfare state, progressive taxation, etc we estimate the risk on disposable income. We find that the standard deviation of permanent labor income (σ_η) equals 0.072 and that the standard deviation of transitory risk is 0.102. We use this value for our expense shock (σ_ω). We set the one-year correlation between permanent income growth and stock market returns to 10%. This corresponds to a θ of 0.040. We approximate the distribution of initial labor income and financial wealth using log-normal distributions. The mean financial wealth for 25-year-old default investors is set to SEK 111,300. The cross-sectional standard deviations are set to 0.391 (σ_z) and 1.365 (σ_A) to match the data for 25-year-old individuals.

Fourth, we match the contribution rates to Sweden. As mentioned before, the total contribution rate to DC accounts are 7% out of observable gross labor income. This corresponds to a contribution rate in the model of 6.54% (0.07/1.07). The contribution rate for the notional account is set to 14.95% (0.16/1.07). The maximum contribution to this account is capped (corresponding to a labor income ceiling of SEK 344,250).

Fifth, we determine the annuity divisor for the notional account in retirement. We use the unisex mortality table of Statistics Sweden to determine ϕ_t. We assume that the notional account continues to be invested in the risk-free bond and allow for inheritances within a cohort from

[8]This corresponds to the ITP1 pension plan for birth cohorts 1979 and younger but abstracting from the increase in contributions above the cap of the notional account.

dying to surviving individuals, incorporating those into the returns of the survivors. We then use the standard annuity formula to reach an annuity factor of 5.6% out of the account balance at age 65. We use the same formulas for the DC account, though we adjust the expected return to the endogenous choice of the DC equity share in retirement.

Finally, we determine the DC equity share profile of the calibration. We use glide path 100-minus-age which is a very common allocation and similar to the default fund in the premium pension plan.

Endogenous parameters and model fit

Four parameters are treated as endogenous in the calibration. We consider data from the working phase.[9] The discount factor (β) is calibrated to match the average ratio of financial wealth to labor income during the working phase (0.922). A β of 0.942 provides an exact fit to the data. The top-left panel of Figure 1 shows the full life-cycle profile of financial wealth. The model fits the financial wealth well up to age 60 and undershoots after that.

The support of the cross-sectional distribution of participation costs is set so that we match the average stock market participation rate between ages 25 and 64. As can be seen in the top-right panel of Figure 1, participation is almost flat over the life-cycle. Intuitively, the parameter $\underline{\kappa}$ affects the participation rate among the young, who are poor in terms of financial wealth and reluctant to enter the stock market if the cost is high. The relatively high participation rate of young individuals therefore leads us to set $\underline{\kappa}$ equal to zero. The parameter $\bar{\kappa}$ is then determined to match the average participation rate from age 25 to 64, which is 0.452 in the model and 0.511 in the data. We obtain this participation rate by setting $\bar{\kappa} = 35,000$. As the distribution is uniform, this corresponds to an average participation cost of SEK 17,500. We find our modeling approach appealing as the

[9]Note that we match the model to data from 2007. This does not allow us to extract cohort or time effects as in, e.g., Ameriks and Zeldes (2004). However, Vestman (2019) finds that cohort and time effects are not strongly present in the data.

uniform distribution of the cost enables the model to replicate the flat participation profile in the data.[10]

Finally, the relative risk aversion coefficient, γ, determines the conditional equity share. We weigh each age group's equity share equally. A relative risk aversion of 14 provides a reasonable fit. The conditional equity share is 0.522 in the model and 0.444 in the data. The lower-left panel of Figure 1 depicts the life-cycle profile. The model overshoots the data when financial wealth is low and undershoots when liquid financial wealth is high. We are reluctant to increase the relative risk aversion above 14, 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 80; however, if value-weighted, this increase is negligible as the financial wealth is small then.

Figure 2 shows that the distribution of entry costs produces an endogenous sorting of individuals into stock market participants and non-participants that matches the data well. The left panel shows that the average labor income of non-participants is similar in the model and the data. The average labor income of participants is somewhat lower than in the data. The right panel shows the financial wealth in the model and in the data. The sorting by financial wealth to participants and non-participants is consistent with the data but weaker.[11] Financial wealth in the model peaks just before retirement, earlier than in the data. In the years after retirement, financial wealth decumulates in the model and the data, but much less so in the latter. In particular, the gap widens for participants. There could be several reasons for this, one being the lack of a bequest motive in the model.

[10]Technically, we approximate the uniform distribution using five equally weighted discrete types (the five costs are equally spaced between zero and SEK 35,000).

[11]It is well known that it is difficult to generate wealth inequality in life-cycle models with incomplete markets. This has been addressed by incorporating heterogeneity in discount factors (Krusell and Smith, 1998) or a right-skewed income process (Castaneda et al., 2003). In our model the progressive feature of the pension system helps us match the data.

4 Individuals' savings motive

We now investigate the determinants of individuals' savings motive. This enables us to design DC pension plans that are less rigid and more tailored to individual circumstances. We do so in three steps.

First, we decompose the precautionary savings motive from the retirement savings motive similar to Gourinchas and Parker (2002). Figure 3 compares life-cycle profiles of the baseline calibration with life-cycle profiles based on solutions and simulations where different components of risk have been turned off. The variable of main interest is financial wealth outside the DC account, reported in the fifth panel. If income shocks and expense shocks are turned off, individuals save substantially less before 45 to 50 years when labor income peaks. In this case financial wealth is still zero at age 50, compared to SEK 400,000 in the baseline calibration. This suggests that a DC pension plan whose savings cannot be used to self-insure against shocks should not have a fixed contribution rate. To be precise, we can derive the savings rate in financial wealth, denoted by $\lambda_{it}^{\mathrm{A}}$, by combining equations (12) and (13):

$$\lambda_{it}^{\mathrm{A}} = \frac{A_{it} - A_{it-1}R_t^a}{Y_{it}} = 1 - \frac{C_{it}}{Y_{it}} - \frac{\kappa_i(I_{it} - I_{it-1})}{Y_{it}}, \tag{16}$$

where the transitory expense shock ω_{it} is set to zero. This is the saving rate out of permanent income. This savings rate is showed in the bottom left panel of figure 3. It shows that the savings rate is zero before age 51 if there are no income or expense shocks. In contrast, savings rates are positive from age 30 in the presence of idiosyncratic shocks. This reveals that the DC account, which is illiquid until age 65, is a poor substitute for financial wealth which is accumulated because of precautionary motives.

Second, we set the contribution rate into the DC account (i.e., λ_{it}) to zero. We label this as a "no-DC plan" pension system. In such a system, individuals rely entirely on the first tier (N_{it}) and their liquid financial wealth (A_{it}) to support themselves in retirement. This system is interesting because it highlights the optimal savings behavior of individuals. Figure 4 reports averages over the life-cycle in the baseline and the "no-DC plan" system. Most notably, consumption is more front loaded. Individuals do not save more in financial wealth in the "no-DC plan" system until age 40. The average savings rate, depicted in the bottom left panel, peaks at 10 percent age 50.

We use the savings rate in the "no-DC plan" to derive a set of "rule of thumb" contribution rates for the DC account. We estimate the following regression equation:

$$\lambda_{it}^{\mathrm{A}} = \beta_0 + \beta_1 A_{it} + \beta_2 Y_{it} + \beta_3 B_{it} + \beta_4 I_{it} + \omega_t + \varepsilon_{it} \tag{17}$$

where ω_t denotes dummy variables for age and ε_{it} is an error term. Table 3 reports the estimates. Column (1) and (2) show that there is no simple linear relationship between age and savings rates. Adding squared term or age fixed effects (column (3)) increases the R-squared substantially. Among the other state variables of the model, labor income is the most important one. A specification with age fixed effects and labor income explains 27 percent of the variance in savings rates (column (4)). Increasing labor income by SEK 100,000 implies an increase in the optimal savings rate by 3 percentage points. If additional state variables are added, the effect of labor income increases to 4 percentage points per SEK 100,000 (columns (5) and (6)). Notably, the dispersion in savings rates due to financial wealth is an order of magnitude smaller. Having exposure to the stock market implies 3.6 percentage points lower savings rate.

As a complement to the regression analysis, figure 5 further illustrates the cross-sectional dispersion in optimal savings rates in the "no-DC plan" system . The top right panel shows the mean savings rate and the second and ninth deciles of the savings rates. There is a great deal of dispersion at all stages of the working life and at 50 it varies between 20 percent and less than zero percent. The other panels to right show that a saving rate is associated with high labor income, high financial wealth, and stock market participation.

5 Flexible DC contribution rates

We now design a DC pension plan with a flexible contribution rate. Informed by the regression estimates, we perform a grid search over different "rule of thumb" contribution rates. Our critera for selection is the rule that maximizes the average welfare gain relative to the baseline calibration and achieves the same average replacement rate. We compute welfare in terms of consumption equivalents.[12] The result of the grid search implies that for a replacement rate as in the baseline calibration, welfare is maximed using the following rule for the contribution rate:

$$\lambda_{it} = 0.10 \times D(45 \leq t \leq 64) + 0.0004 \times Y_{it} - 0.08 \times I_{it}. \tag{18}$$

That is, for each 100,000 SEK in labor income, increase the contribution rate by four percentage points. The positive loading on income implies that the rule provides self-insurance to labor income shocks. All else equal, it implies that financial wealth can be reduced. The rule also proposes that the contribution rate should be reduced by eight percentage points for those that have access to the stock market outside the DC pension plan. Finally, the contribution rate increases by ten percentage points if the individual is older than 44 years. The rule is similar to the estimates reported in column (6) of table 3, which is reassuring.

Figure 6 illustrates the basic implications of this rule. Consumption is frontloaded relative to the baseline, just as in the "no-DC plan" system, and financial wealth peaks at two thirds of the

[12]With Epstein-Zin utility it is straightforward to compute the consumption equivalent associate with each rule. Is proportional to the value function. We define the relevant replacement rate as the replacement if the wealth in all three accounts would be annuitized, that is $(h^B(B_{65}+A_{65})+h^N(N_{65}))/Y_{64}$. The average of this replacement rate is 0.825 in the baseline calibration.

baseline. This is a result of a sharp decline in savings rates in financial wealth after 45 when contributions into the DC account takes off and reaches a peak of 15 percent. It is noteworthy that the DC account balance at 65 in fact is higher than in the baseline whereas financial wealth is lower, leading to similar replacement rates if all accounts would be annuitized.

Figure 7 illustrates the flexibility associated with the rule. The top left panel shows the cross-sectional dispersion in contribution rates. From age 40 and onwards there is a ten percentage-point difference between the second and the ninth decile. This difference is much greater than the baseline calibration's fixed contribution rate. High income individuals save much more than low income individuals. As a result, there is a factor of ten difference in DC account balances between the second and ninth decile at the time of retirement.

Table 4 summarizes the implications for replacement rates and welfare gains. The baseline calibration and the flexible DC pension plan lead to equal replacement rates out of last working year's labor income (83 percent). The flexible plan has the advantage that replacement rates are less dispersed in the cross-section. The standard deviation decreases by 14 percent (0.037/0.264). The flatter consumption profile (i.e., the front loading of consumption) and the added flexibility delivers substantial welfare gains. The average welfare gain, measured as consumption equivalents, is three percent. Only a handful of individuals lose. These individuals are 3.6 standard deviations, or more, below the average gain. Furthermore, the greatest loss is quite limited at only –0.8 percent.

6 Concluding remarks

We investigate the implications of introducing a defined contribution (DC) pension plan that offers more flexibility than typical plans do. We model the first and second tiers of a pension system, where the second tier is a DC pension plan, and embed it into a life-cycle portfolio choice model. We find that a fixed, "rigid", contribution rate is at odds with optimal consumption-savings behavior. It backloads individuals' consumption and does not offer any insurance against shocks. To address this, we propose a flexible design. The design is based on a rule of thumb for the contribution rate. The rule takes age, labor income, and stock market participation outside the pension system as inputs. The rule leads to the same average replacement rate as the fixed contribution rate but at a lower cross-sectional dispersion. There are substantial welfare gains associated with this design. The average gain is three percent of consumption and essentially nobody lose.

References

ALAN, S. (2006): "Entry Costs and Stock Market Participation Over the Life Cycle," *Review of Economic Dynamics*, 9, 588–611.

AMERIKS, J., AND S. P. ZELDES (2004): "How Do Household Portfolio Shares Vary With Age?," Working Paper.

BESHEARS, J., J. J. CHOI, M. IWRY, D. JOHN, D. LAIBSON, AND B. C. MADRIAN (2019): "Building Emergency Savings Through Employer-Sponsored Rainy-Day Savings Accounts," NBER Working Paper No. 26498.

BESHEARS, J., J. J. CHOI, D. LAIBSON, AND B. C. MADRIAN (2018): "Behavioral Household Finance," Handbook of Behavioral Economics, Volume 1, ISSN 2352-2399.

BODIE, Z., R. C. MERTON, AND W. F. SAMUELSON (1992): "Labor Supply Flexibility and Portfolio Choice in a Life Cycle Model," *Journal of Economic Dynamics & Control*, 16, 427–449.

CAMPANALE, C., C. FUGAZZA, AND F. GOMES (2014): "Life-Cycle Portfolio Choice with Liquid and Illiquid Financial Assets," *Journal of Monetary Economics*, 71, 67–83.

CARROLL, C. D., AND A. A. SAMWICK (1997): "The Nature of Precautionary Wealth," *Journal of Monetary Economics*, 40, 41–71.

CASTAÑEDA, A., J. DÍAZ-GIMÉNEZ, AND J.-V. RÍOS-RULL (2003): "Accounting for the U.S. Earnings and Wealth Inequality," *Journal of Political Economy*, 111(4), 818–857.

COCCO, J. A. F., F. J. GOMES, AND P. J. MAENHOUT (2005): "Consumption and Portfolio Choice over the Life Cycle," *Review of Financial Studies*, 18(2), 491–533.

COCCO, J. A. F., AND P. LOPES (2011): "Defined Benefit or Defined Contribution? A Study of Pension Choices," *Journal of Risk and Insurance*, 78, 931–960.

DAHLQUIST, M., J. V. MARTINEZ, AND P. SÖDERLIND (2015): "Individual Investor Activity and Performance," Working Paper.

DAHLQUIST, M., O. SETTY, AND R. VESTMAN (2018): "On the Asset Allocation of a Default Pension Fund," *Journal of Finance*, 73(4), 1893–1936.

EPSTEIN, L. G., AND S. E. ZIN (1989): "Substitution, Risk Aversion, and the Temporal Behavior of Consumption and Asset Returns: A Theoretical Framework," *Econometrica*, 57(4), 937–969.

FAGERENG, A., C. GOTTLIEB, AND L. GUISO (2015): "Asset Market Participation and Portfolio Choice over the Life-Cycle," forthcoming in *Journal of Finance*.

French, E., and J. Jones (2011): "The Effects of Health Insurance and Self-Insurance on Retirement Behavior," *Econometrica*, 79, 693–732.

Gomes, F., and A. Michaelides (2005): "Optimal Life-Cycle Asset Allocation: Understanding the Empirical Evidence," *Journal of Finance*, 60(2), 869–904.

——— (2008): "Asset Pricing with Limited Risk Sharing and Heterogeneous Agents," *Review of Financial Studies*, 21(1), 415–449.

Gomes, F., A. Michaelides, and V. Polkovnichenko (2009): "Optimal Savings with Taxable and Tax-Deferred Accounts," *Review of Economic Dynamics*, 12, 718–735.

Gomes, F. J., L. J. Kotlikoff, and L. 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.

Gourinchas, P.-O., and J. A. Parker (2002): "Consumption over the life cycle," *Econometrica*, 70(1), 47–89.

Krusell, P., and A. A. Smith, Jr. (1998): "Income and Wealth Heterogeneity in the Macroeconomy," *Journal of Political Economy*, 106(5), 867–896.

Lusardi, A., and O. S. Mitchell (2014): "The Economic Importance of Financial Literacy: Theory and Evidence," *Journal of Economic Literature*, 52, 5–44.

OECD (2017): "Pensions at a Glance 2017: OECD and G20 Indicators," OECD Publishing, Paris. http://dx.doi.org/10.1787/pension_glance-2017-en.

Pries, M. J. (2007): "Social Security reform and intertemporal smoothing," *Journal of Economic Dynamics & Control*, 31, 25–54.

Sandris Larsen, L., and C. Munk (2019): "Designing mandatory pension plans," mimeo.

Vestman, R. (2019): "Limited Stock Market Participation Among Renters and Home Owners," *Review of Financial Studies*, 32(4), 1494–1535.

Viceira, L. M. (2001): "Optimal Portfolio Choice for Long-Horizon Investors with Nontradable Labor Income," *Journal of Finance*, 56(2), 433–470.

Table 1: **Calibration – model parameters**

	Notation	Value
Preferences and stock market entry cost		
Discount factor*	β	0.942
Elasticity of intertemporal substitution	$1/\rho$	0.500
Relative risk aversion*	γ	14
Ceiling for stock market entry cost*	$\overline{\kappa}$	35,000
Floor for stock market entry cost*	$\underline{\kappa}$	0
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, expense shock, 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 idiosyncratic expense shock	σ_ω	0.102
Standard deviation of initial labor income	σ_z	0.391
Standard deviation of initial financial wealth	σ_A	1.365
Mean of initial financial wealth	**	111,300
Ceiling for contributions to DC and notional accounts	$\overline{Y}$	344,250
Floor for notional pension	$\underline{Y}$	85,829
Contribution rates in pension accounts		
DC account	λ	6.54%
Notional account	λ^{N}	14.95%
Life-cycle profiles		
Labor-income profile (scaled by 1.07)	g_t	—
Survival rates	ϕ_t	—

The table presents the parameter values of the model. * The parameter value has been determined endogenously by simulation of the model. ** The mean initial financial wealth for 25-year-old default investors, $\exp(\mu_A - \sigma_A^2/2)$, is set to SEK 111,300. The labor-income profiles are discussed in detail in the main text. The survival rates are computed from unisex statistics provided by Statistics Sweden.

Table 2: **Matched Moments in Data and Model**

	Data	Model
Financial wealth-to-labor income ratio	0.922	0.921
Stock market participation	0.511	0.452
Equity share (conditional)	0.444	0.522

The table presents matched moments in the data and model.

Table 3: **Savings rates in the “no-DC” model**

	(1)	(2)	(3)	(4)	(5)	(6)
Constant	-0.0024	-0.1209	-0.1616	-0.2074	-0.2214	-0.2141
	(.)	(.)	(.)	(.)	(.)	(.)
Age (t)	0.0017	0.0186				
	(.)	(.)				
Age^2 (t^2)		–0.0004				
		(.)				
Labor income (Y)				0.0003	0.0004	0.0004
				(.)	(.)	(.)
Financial wealth (A)					–0.00003	–0.00004
					(.)	(.)
Participation dummy (I)						–0.0362
						(.)
R-squared	0.0223	0.1629	0.1715	0.2702	0.2778	0.2859
Age FEs	No	No	Yes	Yes	Yes	Yes
Number of observations	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000

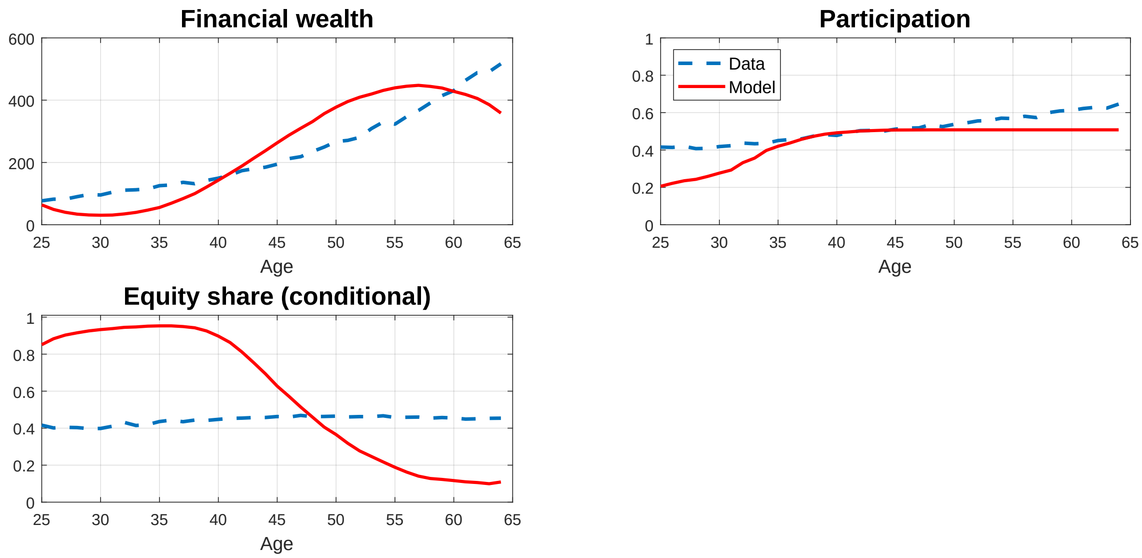
The table presents the results of regressions of the model’s optimal savings rate in financial wealth on some of the model’s state variables if the contribution rate to the DC account (λ_{it}) is zero. The simulated data are based on 50 economies, each of which has 500 investors (500 individuals with five different stock market participation costs) who each work for 40 years. This gives a total of 5,000,000 simulated observations. Labor income and financial wealth are in SEK 1,000s. Standard errors are omitted since they are a function of the size of the simulated sample.

Table 4: **Replacement rates and welfare gains**

	Baseline	Flexible DC
Replacement rates		
Average	0.825	0.831
Standard deviation	0.264	0.227
Maximum	2.292	3.139
Minimum	0.438	0.446
Welfare gains relative to baseline		
Average	—	0.030
Standard deviation	—	0.008
Maximum	—	0.051
Minimum	—	–0.008

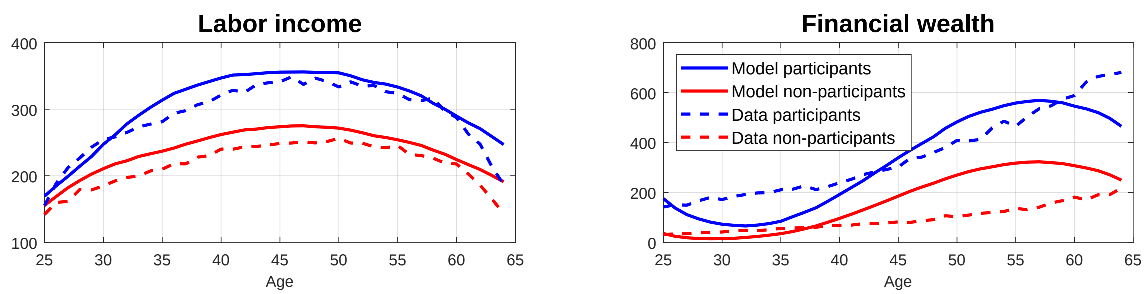
The table presents moments of replacement rates and welfare gains for the baseline line calibration and for flexibel contributions to the DC account (λ_{it} set according to equation (18)).

Figure 1: **Calibration**



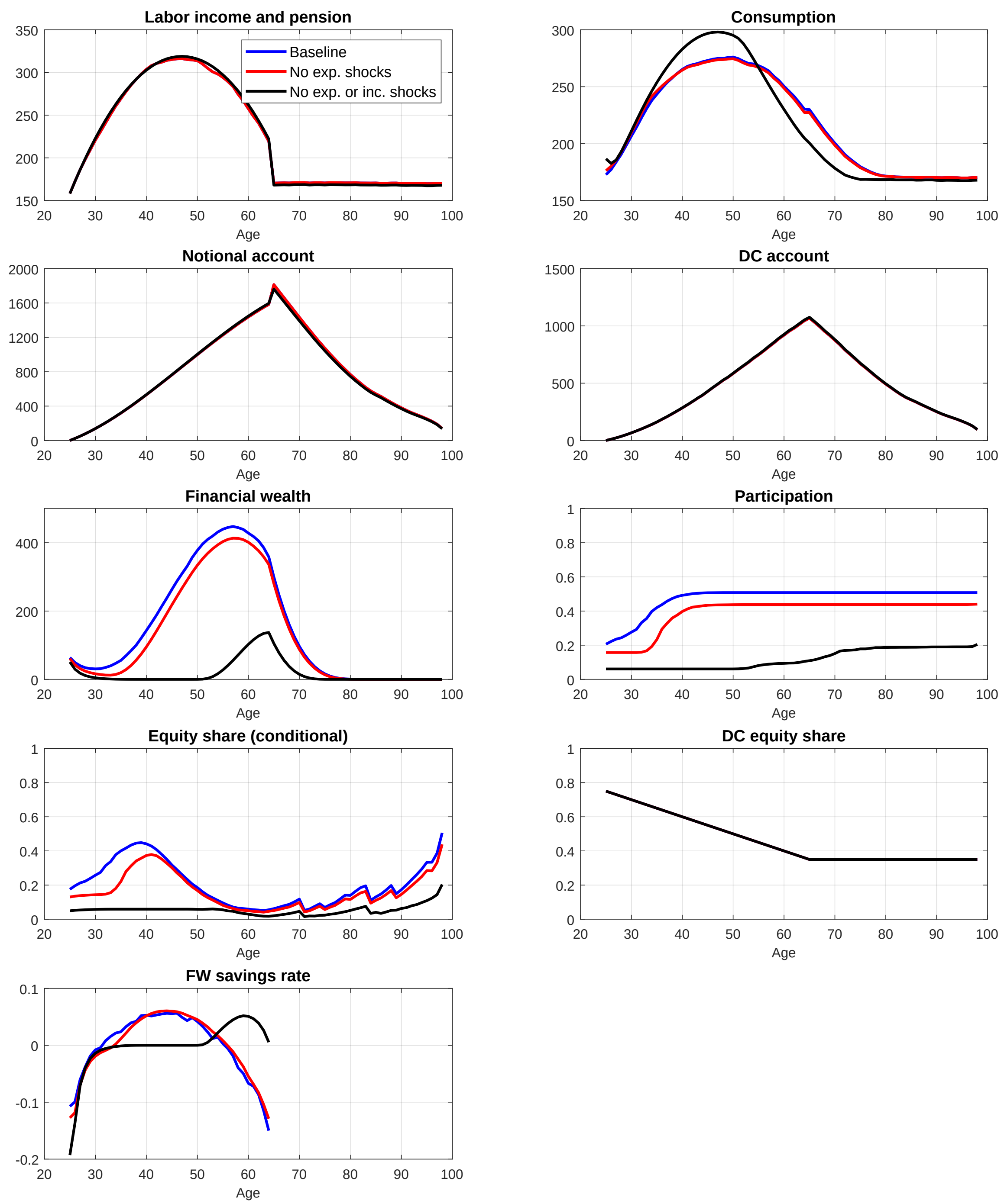
The figure shows the variables that the calibration targets. Financial wealth is expressed in SEK 1000s.

Figure 2: **Model fit**



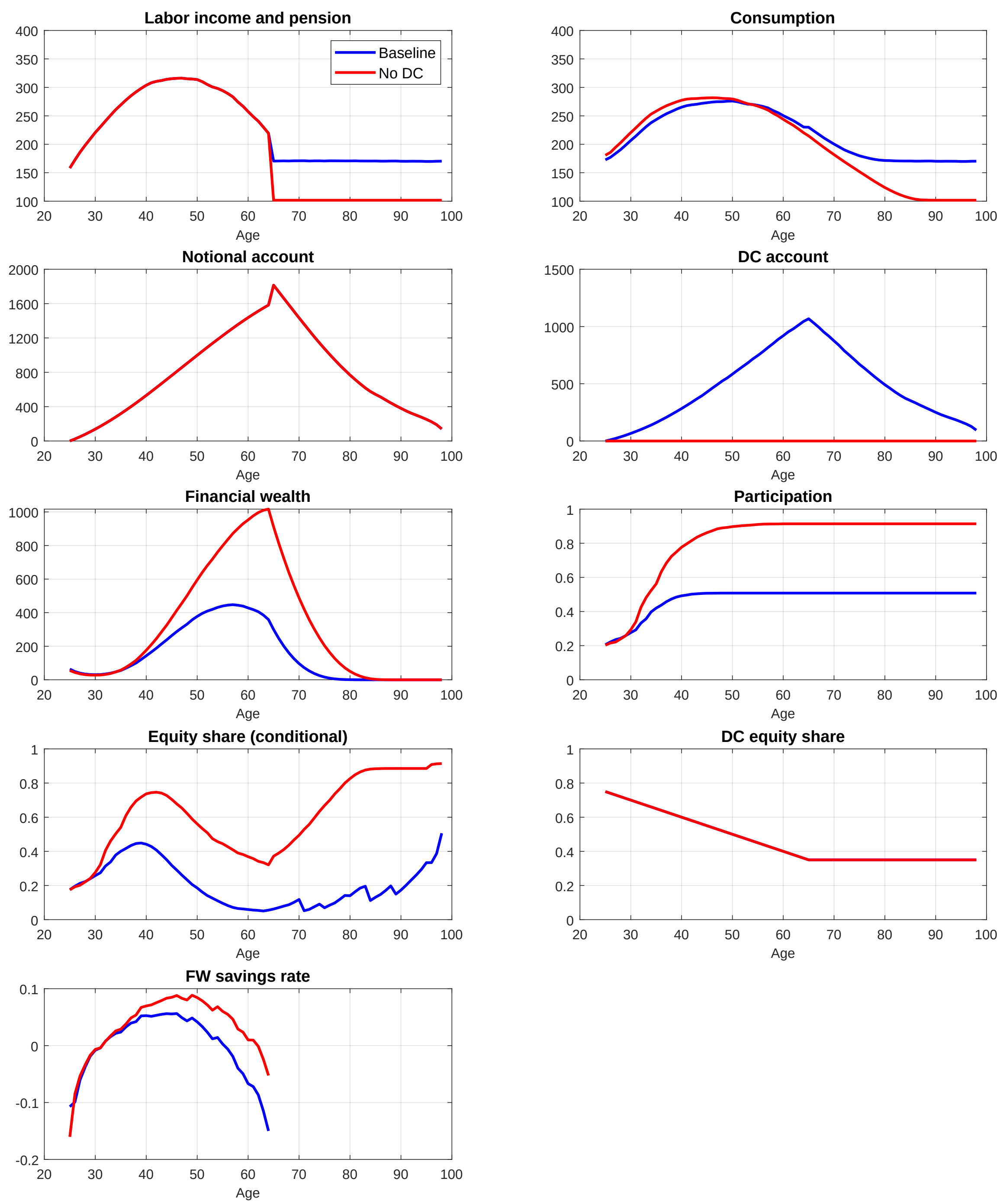
The figure shows labor income and financial wealth conditional on stock market participation. Financial wealth is expressed in SEK 1000s.

Figure 3: **Decomposition of savings motives**



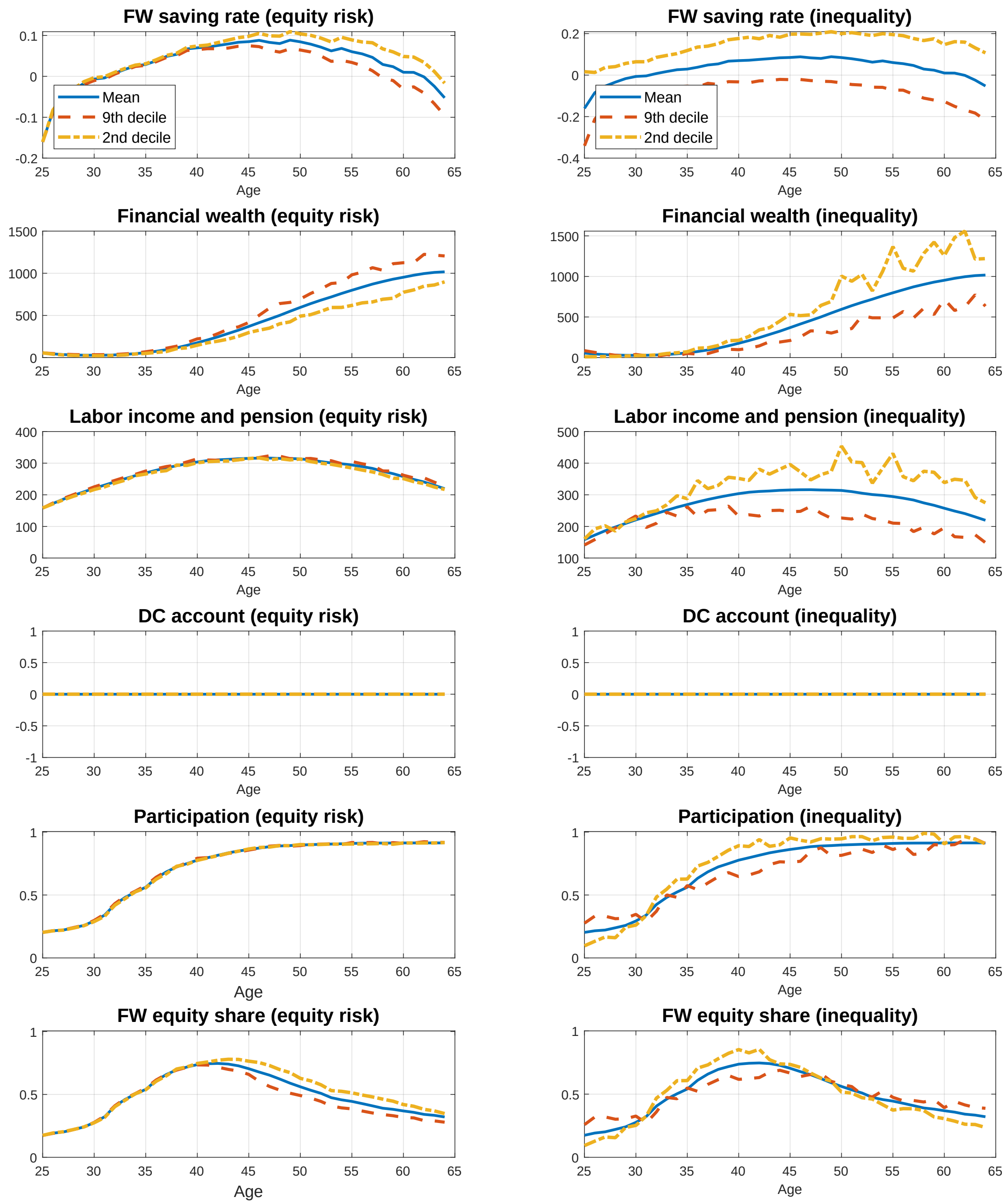
The figure shows averages of variables for three sets of parameter values: the baseline calibration, no expense shocks (σ_ω set to zero), and no expense shocks or income shocks (σ_ω and σ_η set to zero). The bottom left panel plots the savings rate in financial wealth ($\lambda^{\mathrm{A}}_{it}$). Values are expressed in SEK 1000s.

Figure 4: **Baseline vs. "no-DC plan" pension system**



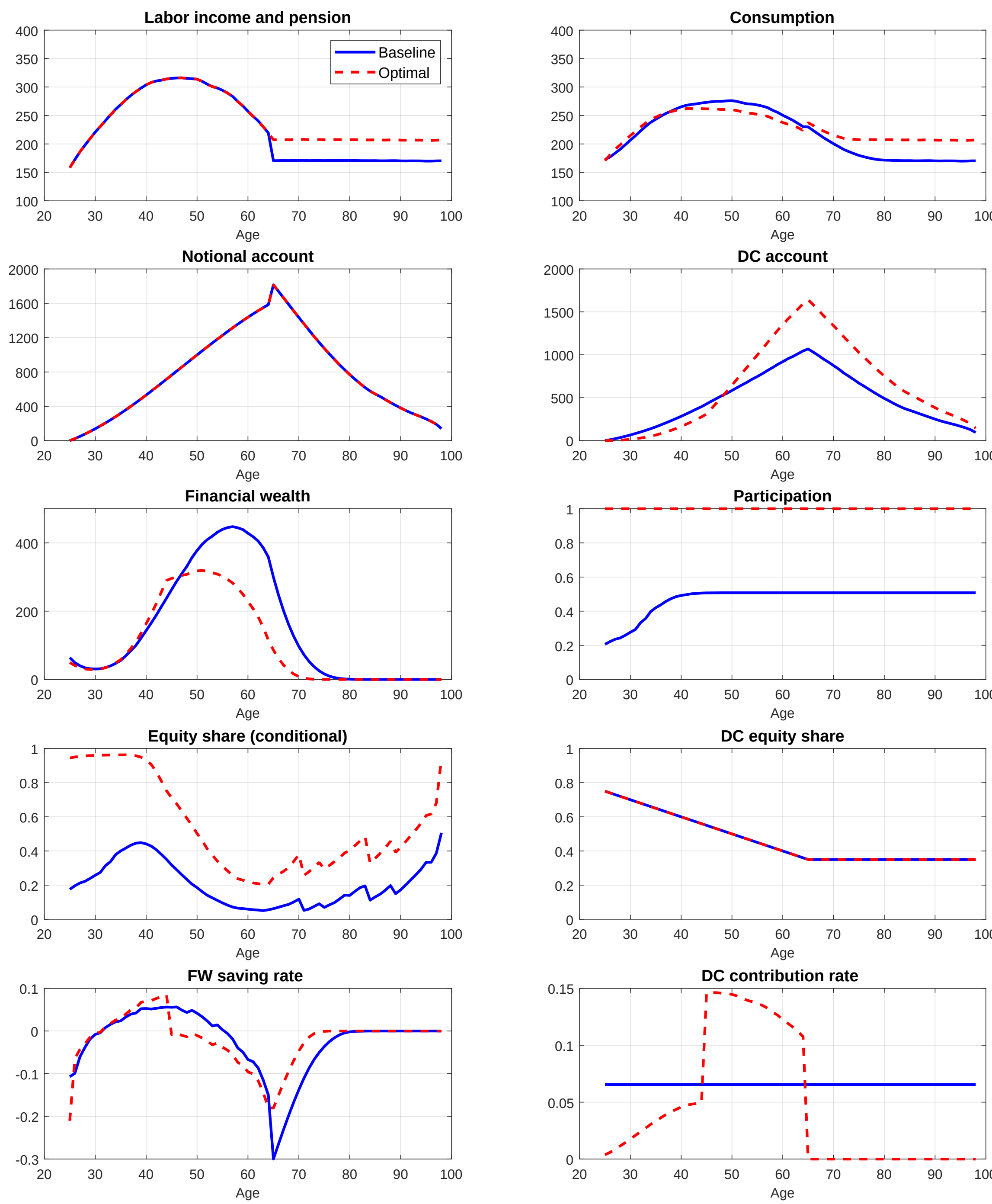
The figure shows averages of variables for two sets of parameter values: the baseline calibration and no contributions to the DC account (λ_{it} set to zero). The bottom left panel plots the savings rate in financial wealth (λ_{it}^{A}). Values are expressed in SEK 1000s.

Figure 5: **Dispersion in the “no-DC plan” pension system**



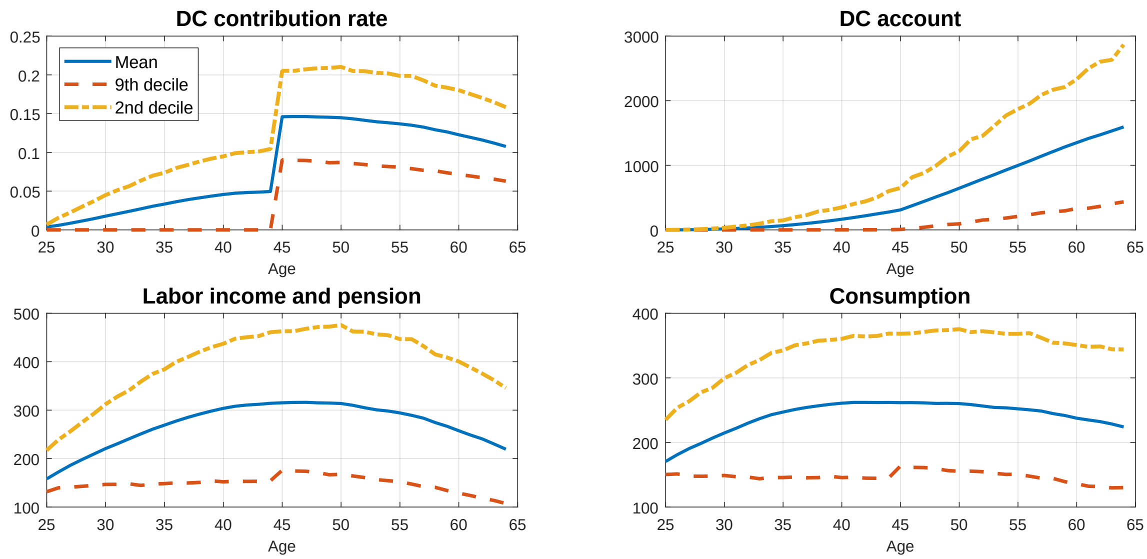
The top panels show the average and the 2nd and 9th deciles of savings rates in financial wealth when there is no DC plan (i.e., λ_{it} set to zero). The other panels show the corresponding values for other variables (i.e., the sorting is based on the top panels). Values are expressed in SEK 1000s.

Figure 6: **Baseline vs. "flexible DC plan"**



The figure shows averages of variables for two sets of parameter values: the baseline calibration and the flexible contributions to the DC account (λ_{it} set according to equation (18)). The bottom left panel plots the savings rate in financial wealth (λ^{A}_{it}) and the bottom right figure plots λ_{it}. Values are expressed in SEK 1000s.

Figure 7: **Cross-sectional dispersion in the “flexible DC plan”**



The figure shows the average and the 2nd and 9th deciles of flexible DC contribution rates (λ_{it} set according to equation (18)). The other three panels show the corresponding values for other variables (i.e., the sorting is based on the flexible DC contribution rate). Values are expressed in SEK 1000s.