Pension Reform and Individual Retirement Accounts *

Julia Le Blanc
Deutsche Bundesbank and Goethe University Frankfurt

Almuth Scholl
University of Konstanz

Abstract

This paper employs a life-cycle model with exogenous stochastic labor income to analyze how different types of individual retirement accounts affect households' savings and portfolio allocation as well as welfare. We consider voluntary accounts as opposed to mandatory accounts that require a minimum contribution rate. Moreover, we contrast add-on accounts with carve-out accounts that replace part of the public social security system. Quantitative results suggest that public retirement systems with mandatory add-on accounts have adverse welfare effects particularly for the young and poor while carve-out accounts are likely to generate welfare gains. In contrast to the previous literature, we find that default portfolio rules have limited welfare consequences.

Keywords: public pension system, individual retirement accounts, household portfolio choice, consumption and saving over the life-cycle
JEL-Codes: E21, H55, G11

*We thank Michael Haliassos and participants of the EEA meeting 2009 for very useful comments and suggestions. The usual disclaimer applies. Please address correspondence to leblanc@ifk-cfs.de or almuth.scholl@uni-konstanz.de.

1 Introduction

This paper examines how the introduction of tax-deferred individual retirement accounts within the social security system - a long-standing policy debate in the U.S. and other countries - affect households' consumption, savings and portfolio allocations decisions as well as welfare.

The paper is motivated by the fact that personal accounts assume a variety of forms in the pension systems of countries around the world. Most economies have some sort of a defined-benefit public retirement system with individual accounts on a voluntary basis while others incorporate mandatory accounts within their social security systems. Examples for voluntary individual retirement accounts of the third pillar are the IRAs or 401(k) in the US and the Riester Pension Plans in Germany. Personal retirement accounts that require compulsory contribution rates on top of the public retirement system have recently been introduced in Sweden, Denmark and Australia[1]. In contrast, in the UK households can decide whether they stay in the current public defined-benefit retirement system and pay contributions to the unfunded social security system or whether they "contract-out" into approved personal pension plans.[2]

In this paper, we build on Gomes, Michaelides and Polkovnichenko (2009) and analyze the quantitative properties of a life-cycle model with exogenous stochastic labor income where households can save in a taxable as well as an illiquid, tax-deferred individual retirement account. In order to hold risky assets in the taxable account households need to pay a fixed stock market entry fee reflecting the explicit transaction costs of opening a brokerage account and the costs of acquiring information. In contrast, investing in stocks is costless in the tax-deferred retirement account. It has been shown by Gomes et al. (2009) that the model captures key features of household-level data, in particular it replicates limited stock market participation, wealth accumulation, and portfolio allocation over the life-cycle. Given our benchmark model, we analyze a battery of different policy experiments, illustrating the effects of pension reforms involving an increased role of individual accounts that are currently under consideration by policymakers in many countries.

As a benchmark, we study the impact of voluntary-add on accounts on consumption, savings, portfolio allocation and welfare. This is the scenario considered by Gomes et al. (2009): households contribute a fraction of their income to the unfunded social security system, and, in addition, have the opportunity to save voluntarily in tax-deferred individual retirement accounts. We then provide a comparison with three alternative forms of pension systems. First, we consider the distributional impact of mandatory add-on accounts. In this scenario, households are required to make compulsory minimum contributions to a funded tax-deferred individual account on top of their contributions to the public defined-benefit retirement system. Second, we analyze the effects of mandatory carve-out

[1] The occupational pension plans in Switzerland and France also fall into this category, see Turner (2006).

[2] Similar systems can also be found in Japan and Peru, see Turner (2006).

accounts that replace a part of the public social security system by individual retirement accounts. In this scenario, households get a rebate on their contributions to the public pension system but are required to invest that amount in the tax-deferred individual account. Third, we allow for voluntary carve-out accounts: households can decide whether they stay in the current social security system and pay contributions to the unfunded social security system or whether they "opt out" of it by making reduced contributions to the public system while investing the carved-out amount in a personal retirement account.

In our benchmark scenario, households save in the voluntary add-on account for two reasons. First, taxation of capital gains is deferred, and, second, the retirement account provides a costless access to risky assets yielding a risk premium. On the other hand, households cannot withdraw funds from their retirement accounts until pension age which makes this account less attractive for households with a high preference for current consumption. Quantitative simulation results show that early in life households save little in the illiquid retirement account but from age 35 contributions start to rise such that wealth accumulation in the tax-deferred retirement account follows a hump shape over the life cycle. Since no stock market entry costs need to be paid, households invest their retirement wealth almost fully in stocks early in life. As public retirement systems with mandatory add-on accounts require compulsory minimum contribution rates, young households are forced to save and, thus, suffer a welfare loss. In contrast, carve-out accounts generate welfare gains since households invest the carved-out retirement savings in risky assets. Only the young and very poor households suffer welfare losses if carve-out retirement accounts became mandatory, and, hence, if they had the choice, they would stick fully to the public funded social security system.

The worldwide trend toward defined contribution plans for retirement in which investment decisions are made by the plan participants themselves has raised concerns about the quality of the decisions being made by the participants that results in low participation rates, infrequent changes of portfolio choice and limited diversification in private pension plans.[3] In this context, plans with default enrollment and default portfolio allocation have been put forward.[4] In our model, we analyze this issue by using default portfolio allocation rules and verify the resulting welfare losses. Interestingly, it turns out that the welfare losses of default rules are very modest.

An important question in public policy is how different income groups react to a change in the social security system. To study this issue we consider the life-cycle income profiles of different education groups and analyze the welfare consequences of the alternative pension systems. Further model

[3]Many authors have pointed out the lack of financial sophistication, e.g. Lusardi (2003), Lusardi and Mitchell (2007). Bernartzi and Thaler (2001) show that many investors evenly spread their contributions across the investment options in a plan, irrespective of the particular options and that ex ante welfare costs of these naive diversification strategies can be substantial.

[4]See e.g. Madrian and Shea (2001), Choi, Laibson, Madrian and Metrick (2002), and Carroll, Choi, Laibson, Madrian and Metrick (2009).

experiments involve the influence of increased background risk such as uncertain public pension income, due to a pension reform during working life or an increase in health-related expenses that are not covered by social security.

The paper is structured as follows. Section 2 discusses the related literature. In section 3 we present the life-cycle model of portfolio choice. Section 4 discusses the calibration of the model. In section 5 we present our quantitative findings considering various policy experiments. Finally, section 6 concludes.

2 Related Literature

A large part of the social security reform literature has focused on the potential general equilibrium impact of various reform proposals and the costs and benefits associated with the transition toward a funded system. Examples of this literature include Auerbach and Kotlikoff (1987), Kotlikoff (1998), Feldstein and Samwick (1998) and De Nardi, Imrohoroglu and Sargent (1999).[5] Given their emphasis on general equilibrium phenomena, these papers often make simplifying assumptions about the actual decision problems that individuals face.

Regarding the structure of analysis of pension reform, Mitchell and Zeldes (1996) present frameworks for social security reform with privatization, and Diamond (1977) explains the background of social security in the U.S. For empirical results on the effectiveness of tax-deferred accounts to increase private retirement saving in the U.S. and their implications on wealth accumulation and savings, see a series of papers by Poterba, Venti and Wise.[6]

In contrast to this literature, our paper focuses on optimal individual behavior in a realistically calibrated life-cycle model of portfolio choice with exogenous stochastic labor income. Our paper is related to Pries (2007) who introduces different personal retirement accounts in a life-cycle model but focuses mainly on labor supply distortions over the life time. Dammon, Spatt and Zhang (2004) and Amromin (2003) study the tax-efficient asset location and allocation decisions with taxable and tax-deferred investing. The effects of social security taxes and different pension systems are not taken into account in these papers. Love (2007) solves and simulates a stochastic life cycle model similar to the one in this paper with a taxable account and a realistically modeled tax-deferred account (401(k) plan). While he shows that optimal contributions to the tax-deferred account are low early in life and then increase, he abstracts from asset allocation within and across the two accounts as well as a bequest motive for saving.

The paper closest to the present one is the one by Gomes et al. (2009) who examine optimal savings with a taxable and a tax-deferred account in a life-cycle model. This paper, however, does not take

[5] More recent examples of this strand of the literature include Menil, Murtin and Sheshinski (2006).

[6] For example, Poterba and Wise (1998), Porterba (1998), Poterba, Venti and Wise (2004).

into account any effect of a social security system on savings in the two accounts and is limited to voluntary tax-deferred add-on accounts only.

The welfare effects of changes in social security rules on households in life-cycle models have been investigated by Campbell, Cocco, Gomes and Maenhout (1999) who simulate the effects of alternative retirement systems on consumption, wealth accumulation and portfolio choice in a partial equilibrium model. This paper, however, does not explicitly model tax-deferred savings accounts.[7]

Our contribution to the literature consists of studying a number of pension policy experiments in a realistically calibrated partial equilibrium model with an individual, tax-deferred retirement account. In particular, we compare life-cycle saving, wealth accumulation and portfolio allocation across different pension systems with individual accounts.

3 The Life-Cycle Model

We build on Gomes et al. (2009) and analyze the quantitative properties of a life-cycle portfolio choice model with exogenous stochastic labor income that features a taxable (TA) as well as an illiquid, tax-deferred (TDA) individual retirement account.

Households live for a maximum of T periods and face an exogenous conditional survival probability p_t, at each age t. Households are characterized by Epstein-Zin-preferences[8] that disentangle the elasticity of intertemporal substitution and risk aversion:

$$V_t = \left\{ (1-\beta) C_t^{1-1/\psi} + \beta (E_t[p_t V_{t+1}^{1-\rho} + (1-p_t) b W_{t+1}^{1-\rho}])^{\frac{1-1/\psi}{1-\rho}} \right\}^{\frac{1}{1-1/\psi}} \tag{1}$$

where C_t denotes consumption and W_t is the sum of cash on hand. Households receive utility from bequests with b determining the strength of the bequest motive. The coefficient of relative risk aversion is denoted by ρ while ψ determines the elasticity of intertemporal substitution. β is the discount factor.

During working life labor income is given by:

$$\begin{aligned} Y_t &= P_t U_t \\ P_t &= \exp(f(t, Z_t)) P_{t-1} N_t \end{aligned}$$

where $f(t, Z_t)$ and P_t denote the deterministic growth and permanent component, respectively. The permanent and transitory shocks, $\ln U_t$ and $\ln N_t$, are independent and identically normally distributed with means $-.5\sigma_U^2$ and $-.5\sigma_N^2$ and variances σ_U^2 and $-.5\sigma_N^2$, respectively.

Retirement is taking place exogenously at age K. Retirement income is characterized by a constant fraction of the last income $Y_t = \lambda P_K$ where λ represents the replacement rate. In addition, households withdraw wealth from their individual retirement account.

[7] Another example is Calvet, Campbell and Sodini (2007).

[8] Epstein and Zin (1989), Weil (1990)

Households choose to invest in a riskless bond and in a risky asset in the TA as well as in the illiquid TDA. Following Gomes et al. (2009) taxes τ_d are paid on nominal returns. Thus, the after-tax real return on the riskless bond is given by

$$\tilde{r}^b = \frac{1 + [(r^b + 1)(1 + \pi) - 1](1 - \tau_d)}{1 + \pi} - 1 \tag{2}$$

where π denotes the constant inflation rate, and r^b the constant real return. There is a risk-premium on holding risky assets:

$$r_t^s - r^b = \mu^s + \epsilon_t^s$$

where μ^s is the equity return and ϵ_t^s is independent and identically normally distributed with mean 0 and variance σ_ϵ^2. The real return on the risky asset is defined as

$$r_t^s = \frac{1 + g_t + d}{1 + \pi} - 1$$

where g_t denotes the nominal capital gain and d is the nominal dividend that are taxed at rates τ_g and τ_d, respectively. Hence, the after-tax real return on the risky asset is

$$\tilde{r}_t^s = \frac{1 + g_t(1 - \tau_g) + d(1 - \tau_d)}{1 + \pi} - 1 \tag{3}$$

Households save in the illiquid TDA for two reasons. Firstly, taxation of capital gains is deferred until retirement and when taxation occurs the tax rates are lower than in the TA where asset returns are taxed upon realization. Secondly, while in the TDA stock market participation is costless, in the TA households have to pay a fixed entry cost before investing in stocks. Thus, investing in the TDA allows to hold stock indirectly without paying the costs that are e.g. associated with the transaction cost from opening a brokerage account.

In the following, we consider different types of TDAs and categorize them by their relationship to social security: they can take the form of an add-on or an carve-out account. Carve-out accounts reduce contributions to and benefits from social security while add-on accounts do not affect the income received from the public pension system but require additional additional contributions. Moreover, we distinguish the individual accounts by their degree of compulsion, i.e. whether participation in individual retirement accounts in voluntary or mandatory.[9]

3.1 Add-On Tax-Deferred Accounts

As benchmark scenario we consider voluntary add-on accounts analyzed by Gomes et al. (2009) and assume that households contribute a fraction of their income to the unfunded social security system

[9]This is by no means a complete description of individual accounts that can have many additional features in reality. For an extended overview of the types of different individual retirement accounts in the social security systems of different countries see Turner (2006).

and, in addition, save for retirement in the TDA. The household may invest in both accounts in a riskless as well as in a risky asset. Let $\alpha_t^r \in [0,1]$ and $\alpha_t^\tau \in [0,1]$ denote the share invested in risky assets in the retirement account and taxable account, respectively.

During working life, cash on hand in the taxable account evolves according to:

$$\begin{aligned} W_{t+1}^\tau = \quad & [\alpha_t^\tau(1+\tilde{r}_{t+1}^s) + (1-\alpha_t^\tau)(1+\tilde{r}^b)](W_t^\tau - C_t - k_t Y_t(1-\tau_d) - I_t FP_t) \\ & +(1-\tau_d-\tau_s)(1-h_{t+1})Y_{t+1} \end{aligned} \tag{4}$$

with $W_{t+1}^\tau \geq 0$. $k_t \in [0, 0.2]$ is the endogenous contribution rate to the individual retirement account and τ_s represents the social security tax. h_t denotes housing expenditures as in Gomes and Michaelides (2005). FP_t denotes the fixed entry cost scaled by the permanent component of labor income. I_t is an indicator function that equals 1 if the fixed entry cost is paid for the first time and zero otherwise. Households who have not yet paid the fixed cost can only invest in the riskless asset in their TA. In this case, $\alpha_t^\tau = 0$.

In the TDA, no taxes are withheld and the investor is free to rebalance his portfolio without creating a tax liability. During working life, cash on hand in the retirement account is given by

$$W_{t+1}^r = [\alpha_t^r(1+r_{t+1}^s) + (1-\alpha_t^r)(1+r^b)](W_t^r + k_t Y_t) \tag{5}$$

with $W_{t+1}^r \geq 0$. r_{t+1}^s and r^b are untaxed returns as opposed to the after-tax return $\tilde{r}_{t+1}^s$ and $\tilde{r}^b$ imposed in the TA.

In retirement, both constraints change to take account of the fact that the household receives income from the withdrawals of the TDA. Hence, cash on hand in the TA is given by:

$$\begin{aligned} W_{t+1}^\tau = \quad & [\alpha_t^\tau(1+\tilde{r}_{t+1}^s) + (1-\alpha_t^\tau)(1+\tilde{r}^b)](W_t^\tau - C_t + (1-\tau_d)Q_t - FIP_t) \\ & +(1-\tau_d)(1-h_{t+1})Y_{t+1} \end{aligned} \tag{6}$$

In retirement, cash on hand in the TDA evolves according to

$$W_{t+1}^r = [\alpha_t^r(1+r_{t+1}^s) + (1-\alpha_t^r)(1+r^b)](W_t^r - Q_t) \tag{7}$$

with

$$Q_t \geq \frac{1}{A_t} W_t^r$$

denoting the minimum withdrawal rate from the TDA during retirement which is equal to the inverse of life expectancy for households.[10] At the time of death, all funds from the TDA are withdrawn untaxed and paid to the beneficiary together with the remaining cash-on hand balance in the TA.

We contrast the voluntary add-on accounts with mandatory add-on accounts that require households to make minimum contributions to the TDA on top of their contributions to the public pension system.

[10] This matches the minimum distribution requirements of DC pension plans in the U.S.

In this variation of the model, households face the additional restriction $k_t \geq k^{min}$ in their budget constraints during working life.

3.2 Carve-out Tax-Deferred Accounts

In contrast to add-on accounts, carve-out accounts replace a part of the public system by individual retirement accounts: households get a rebate on their contributions to the public pension system but are required to invest that amount in the TDA. The carve-out works like a "loan" from social security: the worker borrows from future social security benefits to invest it to an individual tax-deferred retirement account. Workers repay the loan through receipt of reduced social security benefits. To take account of the reduction of future benefits, we need to calculate the accumulation of carved-out contributions, k^c, in a "hypothetical account" (HA) with an interest rate on the hypothetical balance equal to the risk-free rate. These contributions are calculated from the permanent income of the household in time t. Upon retirement, the HA balance resulting from the crediting of contributions and interest is converted into a hypothetical annuity, based on life expectancy at that time. Social security benefits are reduced by this hypothetical annuity.

During working life, the hypothetical wealth accumulation evolves according to:

$$W_K^h = \sum_{t=20}^{K} (1 + r^b)^{K-t} k^c P_t$$

with $k^c > 0$ denotes the carved-out contribution rate from social security. Note that k^c is constant and exogenous.

In retirement the hypothetical wealth decumulation is given by

$$W_{t+1}^h = (1 - \frac{1}{A_K}) W_K^h$$

We consider individual retirement accounts that are mandatory as well as voluntary. Mandatory carve-out accounts require compulsory carve-out contributions to the individual retirement accounts. Accordingly, during working life, the taxable account is given by:

$$\begin{aligned} W_{t+1}^\tau = \quad & [\alpha_t^\tau (1 + \tilde{r}_{t+1}^s) + (1 - \alpha_t^\tau)(1 + \tilde{r}^b)](W_t^\tau - C_t - k_t Y_t (1 - \tau_d) - I_t F P_t) \\ & + (1 - \tau_d - \tau_s^*)(1 - h_{t+1}) Y_{t+1} \end{aligned} \tag{8}$$

with $k_t \geq k^c$, meaning that the household has the opportunity to voluntarily save on top of the carve-out system. Since the household diverts part of its social security contribution k^c to the individual retirement account the social security contributions are reduced to $\tau_s^* = \tau_s - k^c$. During working life, wealth accumulation in the TDA is given by

$$W_{t+1}^\tau = [\alpha_t^\tau (1 + \tilde{r}_{t+1}^s) + (1 - \alpha_t^\tau)(1 + \tilde{r}^b)] S_t^\tau + (1 - \tau_d)(1 - \frac{1}{A_K} W_K^H)(Y_{t+1}) \tag{9}$$

Wealth accumulation in retirement is described by equations (6) and (7)

If carve-out individual retirement accounts are voluntary the household has the choice whether to remain in the social security system or to withdraw from it, either partially, or fully. In exchange for a reduction in both current taxes and future social security benefits, the household who opts out from social security is obliged to contribute to an individual account. This does not affect the household's opportunity to save voluntarily for retirement in TDAs.

In the model, we implement the voluntary carve-out in the following way. The total amount of contributions for retirement saving stays the same, however, the way benefits are calculated differs across the two alternatives. If households decide to stay in the "old" social security plan, upon retirement they receive the defined-benefit pension resulting from their social security contributions. If they decide to carve-out, their future pension benefits get reduced by the hypothetical annuity resulting from the diverted amount of social security contributions accrued by the risk-free rate. In exchange, benefits increase by the annuity resulting from the amount saved in the funded account. The difference to the mandatory carve-out scenario is that the household can now choose whether to contribute fully to the public social security system or to save part of the social security contributions in a funded TDA instead. Thus, the household compares the two value functions associated with having a carve-out account or not:

$$V_t(W_t^\tau, W_t^r, CO_t) = max_{0,1}\Big\{V_t(W_t^\tau, W_t^r, CO_t = 0), V_t(W_t^\tau, W_t^r, CO_t = 1)\Big\}$$

where $CO_t = 1$ denotes the decision for the carve-out (maximization of the value function subject to the constraints of the mandatory carve-out) and $CO_t = 0$ the decision to stick fully to the public social security system (maximization of the value function subject to the constraints of the voluntary add-on) at the time of entry to the labor market, t.

We analyze two different scenarios of a voluntary carve-out. In the first scenario, households can only decide once whether to opt out partially from social security at the beginning of their working life, their decision is irrevocable, and k^c is fixed over their entire working life. In the second scenario, households will be able to take a decision later in their working life. We therefore allow carving out at three different stages in life, at the beginning of working life (age 21), in the middle of working life (age 45) and at the end of working life (age 60). Retirement benefits are calculated depending on the age of the carve-out (i.e. the value that the hypothetical account accrues to).

4 Calibration

Our calibration follows closely Gomes et al. (2009). In particular, in the benchmark scenario of a voluntary add-on account we consider a risk aversion coefficient, $\rho = 4$, the elasticity of intertemporal

substitution, $\psi = 0.35$, a discount rate $\beta = 0.97$ and a bequest preference of $b = 1$. Table 1 summarizes the parametrization of the model. We then vary this baseline parametrization to analyze the behavior of different households.

We employ the estimated income profiles of Cocco, Gomes and Maenhout (2005) that are based on pre-tax non-financial income, i.e. the sum of labor income, unemployment compensation, workers' compensation, social security income, supplemental social security compensation, other welfare and child support as well as total transfers measured from PSID data from 1970 and until 1992. Working life is assumed to start at age 20 for households without any degree and for those with a high school degree, while college graduates are assumed to start working at age 22. Retirement takes place exogenously at age 65 and the replacement rate is set to 0.6. Figure 1 shows the income profiles for different education levels.

During this time, social security contributions started at 4.2% in 1970 and changed several times until reaching 6.2% in 1990 (the social security wage base increases every year). We set the social security tax to 5%. The labor income tax and the tax on capital gains are set to 25% and 20%, respectively.

The fixed stock market entry cost is set to 5% of permanent income which is in line with Gomes et al. (2009).

5 Quantitative Results

5.1 Voluntary Add-On Accounts

We start with the case of a voluntary add-on account to social security. Households have the opportunity to invest in an individual retirement account where wealth accumulates tax-deferred, and they can also hold stocks directly in their taxable account after paying a one time fixed cost that equals 5% of their income.

Given the optimal decision rules from the model, we simulate consumption, saving in the TA, contributions to the retirement account, the risky share in the two accounts and the resulting cash on hand variables and calculate mean contribution rates to the TDA, as well as median wealth-to-net-income ratios in the TA (W_t/Y_t) and the TDA (W_r/Y_t) and the mean of the risky shares (α_t and α_r) in the two accounts that would result if a large number of individuals were born at the same time (i.e. the means and medians of the variables for a particular cohort are calculated across households and across age groups). The life-cycle patterns based on the simulations of the model are summarized in the first column of table 2.

If the TDA takes the form of a voluntary add-on account, wealth accumulation in the TDA and TA features the expected hump shape over the life cycle: young households have a high expected future income against which they cannot borrow. They prefer to consume most of their income and save modestly for precautionary reasons. As labor income increases and the labor income profile becomes

less steep from about 30-35 years of age, agents start saving for retirement and wealth accumulation in the TDA increases.

In the TDA, early in life agents save little for retirement but from around age 35 onwards, the contribution rates to the TDA, k_t, start to increase, and wealth accumulation in the TDA rises fast due to the tax-deferral of returns.

Since young households are liquidity constrained, their marginal utility of consumption is high. As a result, they do not participate directly in the stock market until they have accumulated sufficient wealth. This happens quickly in the first few years after which they pay the fixed entry cost, and the direct participation rate in the stock market reaches 100%. Regarding their portfolio allocation after entering the stock market directly, early in life most agents invest cash-on hand in the TA almost fully in stocks. This is due to the fact that young households are overinvested in human capital and view this non-tradable asset as an implicit riskless asset in their portfolio. As the holdings of this relatively riskfree asset are larger in the early part of life, as soon as young households participate in the stock market they allocate almost all of their assets to stocks. As households grow older and their permanent income decreases, they reduce their exposure to stocks and start investing in cash.[11]

Since households do not need to pay a fixed entry cost to hold stocks in the TDA, they invest their TDA wealth almost fully in stocks early in life. As investors grow older, however, they increasingly shift their portfolio allocation in the TDA towards bonds, the higher-taxed security. Thus, the risky share in the TDA decreases over most of the middle years in the life-cycle.

During retirement, future labor income and financial wealth in both accounts are falling. The potential number of years that households receive public pension income - a close substitute for risk-free asset holdings- decreases. This induces investors to hold more stocks, i.e. agents with low wealth will then tilt their financial portfolio towards stocks more than agents with a large amount of financial wealth as the poorer agents already have a relatively larger risk-free asset position from their retirement income.

5.2 Mandatory Add-on Accounts

The second and third columns of table 2 summarize the life-cycle patterns of the mandatory add-on and the mandatory carve-out scenarios, respectively. In the mandatory add-on scenario a minimum fixed contribution rate to the individual retirement account is required. We choose a minimum fixed contribution rate of 3% of income over the entire working life which is comparable to the mandatory add-on rate in Sweden (2.5%) and other countries. Households can still save more in a tax-deferred account voluntarily.

Comparing wealth-to income ratios over the life cycle with those of the voluntary add-on case, we find that households who have to save for retirement at young ages consequently save less of their

[11] See e.g. Jagannathan and Kocherlakota (1996) for the substitutability between bonds and human capital.

resources in the TA which drives the wealth-to-income ratios down, especially in younger ages. Compared to the benchmark model, the introduction of minimum fixed contribution rates leads to higher median wealth-to-income ratios in the TDA when households are young.
Voluntary contributions to the TDA above the mandatory contributions are "crowded-out". While households with a voluntary add-on account make very small contributions to the TDA in younger ages and increase their retirement savings from age 35 on to more than 7% of their net income until retirement, households with a mandatory add-on account have to save more for retirement in younger years when they would rather consume and then save less in the TDA (0.1% to 1.2%) during the prime years of retirement saving.
Table 2 also displays median welfare losses, calculated as losses in certainty-equivalent consumption, compared to the benchmark scenario. Households living in the mandatory-add-on world suffer welfare losses of 3%, reflecting their mandatory savings from retirement in young years when they would prefer to consume more. As households age and build up wealth, welfare losses decrease.

5.3 Mandatory Carve-out Accounts

The mandatory carve-out scenario has two effects on households: it increases households' net income by giving households a rebate on their social security contributions. At the same time, households have to invest the carved-out amount in the (self-directed) TDA. In retirement, their income from the unfunded public system gets reduced by the annuitized amount to which their carve-out saving rate would have accumulated when invested at the risk-free rate.
Comparing the life-cycle patterns from table 2 with the other two scenarios shows that the mandatory carve-out in the median does not have negative welfare effects on the households. Households benefit from the reduced social security contributions and take advantage of investing their carved-out retirement savings in stocks. As households age, the positive income effect of reduced contribution rate to the social security system during working life dominates the adverse effect of the minimum fixed contribution rate. From early ages on households save as much in the TA as they do in the voluntary add-on account scenario. Thereafter, households' wealth-to income ratios are higher in both accounts compared to both the voluntary add-on and the mandatory add-on scenarios. Already when young, households in this scenario contribute more to the TDA than households in the other two scenarios (due to their higher net income), and the contribution rate over the life cycle stays higher than that of the voluntary add-on.
As a consequence, already very young households experience a welfare gain in certainty-equivalent consumption compared to the voluntary add-on. As households age, the tax rebate of the carve-out results in substantial welfare gains.

5.4 Voluntary Carve-out Accounts

In the voluntary carve-out scenario, households can choose whether they carve out part of their social security contributions (with the consequence of reduced public benefit) or stay in the voluntary add-on scenario with full contributions to the social security system and no change of public pension income. Only young households with very low initial wealth holdings will not carve out at the beginning of working life even if this is their only chance to do so. These households cannot risk their low (retirement) wealth and simultaneously need to accumulate liquid wealth as a buffer against income risk.

We allow households to carve-out at different ages over the life-cycle. In this case, we fix initial wealth to a low level for all young households (initial wealth varies only by the level of income shocks). When households are very young, they suffer from low wealth in the TA. Since the carve-out forces the households to save a minimum contribution rate in the TDA, they choose not to carve-out. As they age and accumulate more wealth, households prefer to have a higher net income during working years that they use to save both in the TDA and the TA. When the budget constraint does not bind anymore, households would contribute more to the TDA than the carve-out rate.

5.5 Investor Heterogeneity

An important question in public policy is how different income groups react to a change in the social security system. In particular, the aim of policymakers is that households from lower income groups should not suffer from substantial welfare losses if a new pension system was introduced. It is a well-established empirical fact that different education levels have different income profiles, see figure 1. In the following we consider the effects of the introduction of each policy on different income levels. We consider households with less than a high school degree (LHS), a high school degree (HS) and college graduates (CD). Table 4 compares the life-cycle patterns of different education levels. The aforementioned numbers refer to the "middle" group of high school graduates and are stated again (in the second column of each scenario).

Households with less than a high school degree have a comparatively flat income profile that starts at an average of 15,000 US$, reaches a maximum of 22,000 US$ at an age below 40 and then decreases. These households do not expect a high income growth and hence need to save from early on. This is reflected in their wealth-to-income ratios: relative to their income, these households accumulate more wealth in both the TA and the TDA than the other education groups. Their savings for retirement kick off from age 21 onwards and stay relatively high during all of working life. Their contribution rate to the TDA is at a lower rate than that of the other income profiles from age 40 which is the time when their income profile starts falling while most of the retirement saving of richer households takes place. However, the fact that households with less than a high school education have relatively high

voluntary contribution rates to the tax-deferred account is a good signal for public policy that aims to attract these households in particular for individual accounts.

High school and college graduates tend to behave differently from households without a degree: they are more abundant in human capital and hence have a stronger motive to invest aggressively in stocks in both accounts. College graduates enter the stock market directly a few years after high school graduates and households who hold no high school degree. This is due to the fact that they start working later and are liquidity-constrained. As these households are "richer" due to their steep income profile, their savings rates are lower than those for the other profiles.

Comparing the welfare effect across different education groups, Table 4 shows that for the very young households, welfare losses in case of the mandatory add-on of the college grads who have the lowest income when young outweigh the welfare losses of high school grads and those without a degree (who have the highest income when young). This changes as households age and the income profile of households without degree becomes flatter. These households suffer from higher welfare losses than the other two groups when they are older.

For the mandatory carve out, a different pattern emerges. While those without a degree and high school graduates have welfare losses in young ages, young college grads already have substantial welfare gains. As households age and accumulate wealth, also the lower income groups gain from the mandatory carve-out.

5.6 Default Portfolio Rules

The worldwide trend toward defined contribution plans for retirement in which investment decisions are made by the plan participants themselves has raised concerns about the quality of the decisions being made by the participants. Many authors have pointed out the lack of financial sophistication[12] that results in low participation rates, infrequent changes of portfolio choice and limited diversification in private pension plans.[13] Bernartzi and Thaler (2002) find that investors might not have coherent preferences and prefer the portfolio chosen by a median investor to their own and Bernartzi and Thaler (2007) emphasize that plan design can change behavior of the less financially sophisticated. In this context, plans with default enrollment and default portfolio allocation have been put forward.[14]

Voluntary add-on accounts in many countries already operate on default investment rules to speed up the increase in participation in TDAs (U.S., Germany). In particular, in pension systems with mandatory individual accounts (mandatory carve-out or mandatory add-on accounts) some individuals are forced to hold an individual account who otherwise would not do so. By providing a default option

[12] See, for example, Lusardi (2003), Lusardi and Mitchell (2007).

[13] Bernartzi and Thaler (2001) show that many investors evenly spread their contributions across the investment options in a plan, irrespective of the particular options and that ex ante welfare costs of these naive diversification strategies can be substantial.

[14] See, for example, Madrian and Shea (2001), Choi et al. (2002), and Carroll et al. (2009).

these individuals get a guideline how to invest if they prefer not to take an active decision. Therefore, pension systems with mandatory accounts typically provide default portfolio allocation options. For example, in Sweden, the default fund, offered to participants in the Premium Pension System that do not want to take an active decision, is a fixed allocation of stocks and bonds where equity holdings cannot exceed 90% and may not fall below 80%. This fund reflects the Swedish governments' intention to achieve a high long-run rate of return at an overall low risk level.[15], [16]

We study the effect of default portfolio allocation rules in voluntary add-on accounts, mandatory add-on plans and mandatory carve-out plans. Introducing a default rule affects the model in the following way: α_t^r is fixed (no choice variable) and individuals face a fixed risky share following a simple $1/n$ rule of thumb ($\alpha_t^r = 0.5$) or a deterministically decreasing, exogenously fixed portfolio share mimicking a life-cycle fund ($\alpha_t^r = (100 - age)\%$).

In the first three columns, table 5 displays the life-cycle behavior of households in the voluntary add-on scenario when choosing α_r endogenously compared to the simple rule of thumb (when the portfolio allocation rule is to allocate evenly between the investment options) and an age rule that fixes α_r at a linearly decreasing share of $(100 - age)\%$, making retirement savings more risky when the household is still young and lowering the risky share over life. Surprisingly, life-cycle patterns differ only slightly compared to the case of the optimally chosen risky share although the optimal risky share differs substantially from the default rule. As a result, welfare losses of the voluntary add-on account with either one of the default rules compared to the model with endogenous α_r are low even in young ages and increase slightly as households age. Interestingly, losses are higher for the age rule and reach 0.6% at age 30.

Table 5 also shows results for the mandatory add-on and the mandatory carve-out accounts with the same default rules. Default rules become especially important in systems with a mandatory individual account as these also force agents to save in retirement accounts who would otherwise not do so. As with the voluntary add-on, life-cycle patterns within each scenario differ very little, especially the contributions to the TDA stay the same. There are small welfare consequences of introducing default rules in mandatory individual account systems compared to endogenously choosing the optimal risky share.

5.7 Pension Reform

We have modeled the different policy experiments as if they were available from age 20 onwards for the rest of households' lives. In reality, the political process takes a long time before reforming

[15] Cronqvist and Thaler (2007) and Sunden (2006).

[16] Should personal retirement accounts be established as a default saving vehicle in the US, the default fund is likely to be more conservative , in form of an all-bond default option (such as one fund of the Federal Thrift Saving Plan) or a life-cycle portfolio plan, starting at 85% in stocks through age 29 and the gradually falling to 15% by age 60 or a 50 per cent stock portfolio as featured by the President's (Bush) Commission to Strengthen Social Security (Cogan and Mitchell (2003)).

an existing pension system. Including probabilities that a new system with mandatory individual accounts is introduced each period is a way to model the uncertainty in timing and realization of a pension reform during working life. In this scenario, the household faces in each period a certain probability of experiencing a pension reform involving individual accounts. For example, following the discussion in the US about voluntary carve out plans from social security, a household might perceive the probability of their introduction as having a 10% chance each year until he reaches retirement.

The first two columns of table 6 display the life-cycle behavior when households are faced with a per-period probability of the introduction of a pension reform from the benchmark model of a voluntary add-on account to a mandatory add-on account. If a pension reform takes place each period with a probability of 30%, households save more in the TDA, especially from age 50 onwards. If the probability of a reform increases to 50% in each period, they have welfare losses of 3.5% at the beginning of working life compared to 2%.

5.8 Uncertain Retirement Income

An alternative possibility to model the effects of a pension reform during working life is an uncertain retirement income draw in the last period of working life. Recent pension reforms have usually involved a decrease in public pension benefits, and to the extent that the reform is perceived as uncertain, retirement income can be modeled as a shock. Hence, this specification introduces significant background risk during retirement and could reveal the sensitivity of the benchmark results to the assumption of nonrandom retirement income.

In the model, only in the last period before retirement the household gets to know his retirement income, i.e. with a probability of 0.5 the household will end up with the retirement income λ of the calibrated level of 60% of pre-retirement income, however, with a probability of 0.5 he will end up with only half of the replacement rate λ. Once retired, the household has certain retirement income, either low or high.

In the following experiments, we introduce substantial uncertainty about future income into the benchmark scenario of the voluntary add-on account. This experiment is used to analyze households' reaction when faced with uncertain future pension reforms that are more realistic than the introduction of a mandatory add-on or carve-out at the beginning of the life-cycle.

Table 6 displays two different setups: The first two columns show life-cycle behavior when households are faced with a per-period probability of the introduction of a pension reform from the benchmark model of a voluntary add-on account to a mandatory add-on account. If a pension reform takes place each period with a probability of 30%, households save more in the TDA, especially from age 50 onwards. If the probability of a reform increases to 50% in each period, they have welfare losses

of 3.5% at the beginning of working life compared to 2%.
The second two columns show life-cycle behavior if households face an uncertain retirement income. As pension reforms are always connected to lowering replacement rates, households in this experiment have substantial insecurity regarding their public pension benefits: with a probability of 0.5, they expect their retirement income to be the calibrated pre-reform replacement rate of 60% of last income and with the same probability expect public pension income to drop to only 50% of the current replacement rate. (We also experimented with an even sharper drop to only 25% of the replacement rate.) The possibility of having a substantially lower retirement income increases households' saving both in the TA and the TDA. In particular, households make higher contributions to the TDA from young ages onwards.

6 Conclusion

In this paper, we have analyzed life-cycle saving, wealth accumulation and portfolio allocation decisions in a model with a taxable account and a tax-deferred retirement account in the presence of uninsurable labor income risk and borrowing constraints. In our policy experiments, we have varied the roles individual retirement accounts assume in the public social security system and have examined the effects on households' life-cycle decisions depending on the type of account implemented.
Deviating from the benchmark case of a voluntary add-on account, we first have introduced a mandatory add-on account. Our results confirm the hypothesis that forcing agents to save a minimum fraction of their income in individual accounts crowds out other savings they would voluntarily undertake at later stages in life. Moreover, when faced with a mandatory contribution rate, agents reduce consumption not just in younger ages. Across education levels, mandatory add-on accounts have the most adverse effects on young households with low income. These households reduce savings substantially in both the TA and the TDA and moreover reduce average consumption by an average of 10% over the entire life. Mandatory carve-out accounts, on the contrary, have ambiguous results: as net income increases, it can be beneficial for households to direct a part of their social security contributions to their TDA where they can invest their retirement eggs in assets with higher returns. Therefore, mandatory carve-outs can be welfare-enhancing for richer, older or better educated households in particular.
In the context of the public policy debate of whether individual accounts should become a mandatory component of social security, our results point towards the opposite direction. If households could choose the role of individual accounts in their pension portfolio, they would prefer to have voluntary add-on accounts when young and carve-out accounts when older (or richer). Mandatory add-on accounts are always and for all household groups welfare decreasing.
Default portfolio allocation rules that guide households with their investment decisions have only

small negative welfare effects which is important given that many households may not be able to make informed investment decisions and instead rely on default rules. Policy makers who introduce individual accounts with default rules do not crowd out savings and only decrease households' welfare marginally.

An outlook to further scenarios includes modeling the role of individual accounts in case of a financial crisis that wipes out most of retirement wealth of households. With the financial crisis hitting the pension landscape all over the World, many people have lost a big part of their defined-contribution pensions, whether these were employer-sponsored plans or individually directed plans. However, in view of the current discussion on countries defaulting on their bonds, it remains to be seen whether these can be referred to as risk-free assets. Given the current setup and the heightened insecurity on stock and bond markets, the riskiness of relying on stocks or bonds for retirement saving might be underestimated.

A Solving the Model

In the benchmark scenario of a voluntary add-on account, households maximize

$$V_t = \left\{(1-\beta)C_t^{1-1/\psi} + \beta(E_t[p_t V_{t+1}^{1-\rho} + (1-p_t)bW_{t+1}^{1-\rho}])^{\frac{1-1/\psi}{1-\rho}}\right\}^{\frac{1}{1-1/\psi}}$$

s.t.

$$\begin{aligned}
W_t^\tau \leq \quad & C_t + S_t^\tau + k_t Y_t(1-\tau_d), \text{ during working life} \\
W_t^\tau \leq \quad & C_t + S_t^\tau - (1-\tau_d)Q_t, \text{ during retirement} \\
W_{t+1}^\tau = \quad & [\alpha_t^\tau(1+\tilde{r}_{t+1}^s) + (1-\alpha_t^\tau)(1+\tilde{r}^b)]S_t^\tau \\
& +(1-\tau_d-\tau_s)(1-h_{t+1})Y_{t+1} \\
W_{t+1}^r = \quad & [\alpha_t^r(1+r_{t+1}^s) + (1-\alpha_t^r)(1+r^b)](W_t^r + k_t Y_t), \\
\\
W_{t+1}^r = \quad & [\alpha_t^r(1+r_{t+1}^s) + (1-\alpha_t^r)(1+r^b)](W_t^r - Q_t), \\
\\
Q_t \geq \quad & \frac{1}{A_t}W_t^r, \ t \geq 70 \\
C_t \geq \quad & 0 \\
\alpha_t^\tau, \alpha_t^r \in \quad & [0,1] \\
W_{t+1}^\tau, W_{t+1}^r \geq \quad & 0
\end{aligned}$$

To solve the model we normalize all constraints and the value function by the permanent income component, P_t. This way, we can reduce the number of state variables. In normalized terms, our model reads the following way:

A.1 Normalized Model

$$
\begin{aligned}
v_t(w_t^\tau, w_t^r) = \quad & max\Big\{(1-\beta)c_t^{1-1/\psi} \\
+ \quad & \beta(E_t(\frac{P_{t+1}}{P_t})^{1-\rho}[p_t v_{t+1}(w_{t+1}^\tau, w_{t+1}^r)^{1-\rho} + (1-p_t)b(w_{t+1})^{1-\rho}])^{\frac{1-1/\psi}{1-\rho}}\Big\}^{\frac{1}{1-1/\psi}} \\
s.t. & \\
c_t \geq \quad & w_t^\tau - s_t^\tau - \tilde{k}_t(1-\tau_d), \text{ during working life} \\
c_t \geq \quad & w_t^\tau - s_t^\tau + q_t(1-\tau_d), \text{ during retirement} \\
w_{t+1}^\tau = \quad & [\alpha_t^\tau(1+\tilde{r}_{t+1}^s) + (1-\alpha_t^\tau)(1+\tilde{r}^b)]\frac{s_t^\tau}{Z_{t+1}} + (1-\tau_d)(1-h_{t+1})U_{t+1}, \\
& \text{during working life and retirement} \\
w_{t+1}^r = \quad & [\alpha_t^r(1+r_{t+1}^s) + (1-\alpha_t^r)(1+r^b)]\frac{w_t^r + \tilde{k}_t}{Z_{t+1}}, \text{ during working life} \\
w_{t+1}^r = \quad & [\alpha_t^r(1+r_{t+1}^s) + (1-\alpha_t^r)(1+r^b)]\frac{w_t^r - q_t}{Z_{t+1}}, \text{ during retirement} \\
q_t \geq \quad & \frac{1}{A_t}w_t^r, \ t \geq 70 \\
\tilde{k}_t = \quad & k_t U_t \\
c_t \geq \quad & 0 \\
\alpha_t^\tau, \alpha_t^r \in \quad & [0,1] \\
w_{t+1}^\tau, w_{t+1}^r \geq \quad & 0
\end{aligned}
$$

with $v_t(w_t) = P_t V_t(w_t)$

We solve the model numerically by employing grid search.

B Welfare

To evaluate the welfare consequences of a change in policy, we calculate certainty-equivalent consumption for each scenario. More specifically, for each policy scenario we compute the constant consumption stream that makes the household as well off in expected utility terms as the consumption stream that the household optimally chooses under this rule. Relative welfare gains/losses are then obtained by measuring the change in equivalent consumption that would occur if we deviate from the benchmark model of a voluntary add-on account.

Recall that the preferences of the model are given by:

$$V_t = \Big\{(1-\beta)C_t^{1-1/\psi} + \beta(E_t[p_t V_{t+1}^{1-\rho} + (1-p_t)bW_{t+1}^{1-\rho}])^{\frac{1-1/\psi}{1-\rho}}\Big\}^{\frac{1}{1-1/\psi}}$$

Neglecting the bequest motive this reduces to:

$$V_t = \Big\{(1-\beta)C_t^{1-1/\psi} + \beta(E_t[p_t V_{t+1}^{1-\rho}])^{\frac{1-1/\psi}{1-\rho}}\Big\}^{\frac{1}{1-1/\psi}}$$

First, we compute expected life-time utility of the benchmark case, V_1^b, by backward recursion from the end of life as follows:

- In $T-1$:

$$\begin{aligned} V_{T-1}^b(W_{T-1}) = & \quad \left\{(1-\beta)C_{T-1}^{1-1/\psi}\right\}^{\frac{1}{1-1/\psi}} \\ \Leftrightarrow V_{T-1}^b(W_{T-1}) = & \quad (1-\beta)^{\frac{1}{1-1/\psi}} C_{T-1} \end{aligned}$$

- In $T-2$:

$$\begin{aligned} V_{T-2}^b(W_{T-2}) = & \quad \left\{(1-\beta)C_{T-2}^{1-1/\psi} + \beta(E_{T-2}[p_{T-2}V_{T-1}^{1-\rho}])^{\frac{1-1/\psi}{1-\rho}}\right\}^{\frac{1}{1-1/\psi}} \\ \Leftrightarrow V_{T-2}^b(W_{T-2}) = & \quad \left\{(1-\beta)C_{T-2}^{1-1/\psi}\right. \\ & + \quad \left.\beta(p_{T-2}((1-\beta)^{\frac{1}{1-1/\psi}} C_{T-1})^{1-\rho})^{\frac{1-1/\psi}{1-\rho}}\right\}^{\frac{1}{1-1/\psi}} \end{aligned}$$

As we look for the constant consumption stream that would give the same utility, $C_{T-1} = C_{T-2} = \overline{C^b}$

$$\begin{aligned} \Leftrightarrow V_{T-2}^b(W_{T-2}) = & \quad \left\{(1-\beta)\overline{C^b}^{1-1/\psi}\right. \\ & + \quad \left.\beta(p_{T-2}((1-\beta)^{\frac{1}{1-1/\psi}}\overline{C^b})^{1-\rho})^{\frac{1-1/\psi}{1-\rho}}\right\}^{\frac{1}{1-1/\psi}} \\ \Leftrightarrow V_{T-2}^b(W_{T-2}) = & \quad \left\{(1-\beta)\overline{C^b}^{1-1/\psi}\right. \\ & + \quad \left.\beta(p_{T-2}^{\frac{1-1/\psi}{1-\rho}}((1-\beta)^{\frac{1}{1-1/\psi}}\overline{C^b}))^{1-1/\psi}\right\}^{\frac{1}{1-1/\psi}} \\ \Leftrightarrow V_{T-2}^b(W_{T-2}) = & \quad \left\{(1-\beta)\overline{C^b}^{1-1/\psi}\right. \\ & + \quad \left.\beta p_{T-2}^{\frac{1-1/\psi}{1-\rho}}(1-\beta)\overline{C^b}^{1-1/\psi}\right\}^{\frac{1}{1-1/\psi}} \\ \Leftrightarrow V_{T-2}^b(W_{T-2}) = & \quad \left\{(1-\beta)\overline{C^b}^{1-1/\psi}(1+\beta p_{T-2}^{\frac{1-1/\psi}{1-\rho}})\right\}^{\frac{1}{1-1/\psi}} \\ \Leftrightarrow V_{T-2}^b(W_{T-2}) = & \quad (1-\beta)^{\frac{1}{1-1/\psi}}\overline{C^b}(1+\beta p_{T-2}^{\frac{1-1/\psi}{1-\rho}})^{\frac{1}{1-1/\psi}} \end{aligned}$$

- In $T-3$:

$$
\begin{aligned}
V^b_{T-3}(W_{T-3}) = \quad & \Big\{(1-\beta)\overline{C^b}^{1-1/\psi}_{T-3} + \beta(E_{T-3}[p_{T-3}V^{1-\rho}_{T-2}])^{\frac{1-1/\psi}{1-\rho}}\Big\}^{\frac{1}{1-1/\psi}} \\
\Leftrightarrow V^b_{T-3}(W_{T-3}) = \quad & \Big\{(1-\beta)\overline{C^b}^{1-1/\psi} \\
+ \quad & \beta(p_{T-3}((1-\beta)^{\frac{1}{1-1/\psi}}C(1+\beta p_{T-2}^{\frac{1-1/\psi}{1-\rho}})^{\frac{1}{1-1/\psi}})^{1-\rho})^{\frac{1-1/\psi}{1-\rho}}\Big\}^{\frac{1}{1-1/\psi}} \\
\Leftrightarrow V^b_{T-3}(W_{T-3}) = \quad & \Big\{(1-\beta)\overline{C^b}^{1-1/\psi} \\
+ \quad & \beta(p_{T-3}^{\frac{1-1/\psi}{1-\rho}}((1-\beta)^{\frac{1}{1-1/\psi}}\overline{C^b}(1+\beta p_{T-2}^{\frac{1-1/\psi}{1-\rho}})^{\frac{1}{1-1/\psi}})^{1-1/\psi})\Big\}^{\frac{1}{1-1/\psi}} \\
\Leftrightarrow V^b_{T-3}(W_{T-3}) = \quad & \Big\{(1-\beta)\overline{C^b}^{1-1/\psi} \\
+ \quad & \beta(p_{T-3}^{\frac{1-1/\psi}{1-\rho}}(1-\beta)\overline{C^b}^{1-1/\psi}(1+\beta p_{T-2}^{\frac{1-1/\psi}{1-\rho}}))\Big\}^{\frac{1}{1-1/\psi}} \\
\Leftrightarrow V^b_{T-3}(W_{T-3}) = \quad & \Big\{(1-\beta)\overline{C^b}^{1-1/\psi} \\
+ \quad & \beta p_{T-3}^{\frac{1-1/\psi}{1-\rho}}(1-\beta)\overline{C^b}^{1-1/\psi}(1+\beta p_{T-2}^{\frac{1-1/\psi}{1-\rho}})\Big\}^{\frac{1}{1-1/\psi}} \\
\Leftrightarrow V^b_{T-3}(W_{T-3}) = \quad & \Big\{(1-\beta)\overline{C^b}^{1-1/\psi}(1+\beta p_{T-3}^{\frac{1-1/\psi}{1-\rho}}(1+\beta p_{T-2}^{\frac{1-1/\psi}{1-\rho}}))\Big\}^{\frac{1}{1-1/\psi}} \\
\Leftrightarrow V^b_{T-3}(W_{T-3}) = \quad & \Big\{(1-\beta)\overline{C^b}^{1-1/\psi}(1+\beta p_{T-3}^{\frac{1-1/\psi}{1-\rho}} + \beta^2 p_{T-3}^{\frac{1-1/\psi}{1-\rho}} p_{T-2}^{\frac{1-1/\psi}{1-\rho}})\Big\}^{\frac{1}{1-1/\psi}} \\
\Leftrightarrow V^b_{T-3}(W_{T-3}) = \quad & (1-\beta)^{\frac{1}{1-1/\psi}}\overline{C^b}(1+\beta p_{T-3}^{\frac{1-1/\psi}{1-\rho}} + \beta^2 p_{T-3}^{\frac{1-1/\psi}{1-\rho}} p_{T-2}^{\frac{1-1/\psi}{1-\rho}})^{\frac{1}{1-1/\psi}}
\end{aligned}
$$

- In $t = 1$ the life-time utility of a constant consumption stream that makes the investor as well off as his optimal per-period decisions in the benchmark case is:

$$
\begin{aligned}
V^b_1(W_1) = \quad & (1-\beta)^{\frac{1}{1-1/\psi}}\overline{C^b}(\sum_{t=1}^{T}\beta^{t-1}\prod_{j=0}^{t-1}p_j^{\frac{1-1/\psi}{1-\rho}})^{\frac{1}{1-1/\psi}} \\
= \quad & \overline{C^b}\Big\{(1-\beta)\sum_{t=1}^{T}\beta^{t-1}\prod_{j=0}^{t-1}p_j^{\frac{1-1/\psi}{1-\rho}}\Big\}^{\frac{1}{1-1/\psi}}
\end{aligned}
$$

Recall that $p_0 = 1$, i.e. the probability to survive is equal to one in the first period of life.
Reformulate for $\overline{C^b}$:

$$
\begin{aligned}
V^b_1(W_1) = \quad & \overline{C^b}((1-\beta)\sum_{t=1}^{T}\beta^{t-1}\prod_{j=0}^{t-1}p_j^{\frac{1-1/\psi}{1-\rho}})^{\frac{1}{1-1/\psi}} \\
\Leftrightarrow \overline{C^b} = \quad & \frac{V^b_1(W_1)}{((1-\beta)\sum_{t=1}^{T}\beta^{t-1}\prod_{j=0}^{t-1}p_j^{\frac{1-1/\psi}{1-\rho}})^{\frac{1}{1-1/\psi}}}
\end{aligned}
$$

where $\overline{C^b}$ is the constant consumption that yields the same life-time utility as the optimal decision rule each period.

Second, we calculate the life-time utility of each of the reform scenarios described above. For example, the life-time utility and the certainty-equivalent consumption of the mandatory add-on case are

given by:

$$V_1^m(W_1) = \quad \overline{C}^m((1-\beta)\sum_{t=1}^{T}\beta^{t-1}\prod_{j=0}^{t-1}p_j^{\frac{1-1/\psi}{1-\rho}})^{\frac{1}{1-1/\psi}}$$

$$\Leftrightarrow \overline{C}^m = \quad \frac{V_1^m(W_1)}{((1-\beta)\sum_{t=1}^{T}\beta^{t-1}\prod_{j=0}^{t-1}p_j^{\frac{1-1/\psi}{1-\rho}})^{\frac{1}{1-1/\psi}}}$$

Finally, the welfare gain/loss of the policy experiment over the benchmark scenario is given by:

$$L^m = \frac{\overline{C^b} - \overline{C}^m}{\overline{C}^m} = \frac{V_1^b - V_1^m}{V_1^m}$$

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Table 1: Model Parameters

Preferences	ρ	Risk aversion	4
	b	Bequest Intensity	1
	ψ	EIS	0.35
	β	Discount rate	0.97
Labor income	σ_u	Transitory shock	0.10
process	σ_n	Persistent shock	0.10
	λ	Replacement rate	0.60
Asset returns	r^b	Real bond return	0.02
	μ^s	Equity premium	0.04
	σ_{ϵ^s}	Standard deviation	0.20
	$Corr(\epsilon_t, lnN_t)$	Corr(stock returns, permanent labor inc shocks)	0.15
	$Corr(\epsilon_t, lnU_t)$	Corr(stock returns, transitory labor inc shocks)	0
	F	Fixed Cost of Stock Market Participation	0.05
Taxes	τ_d	Tax on dividends, labor income	0.25
	τ_g	Tax on capital gains	0.20
	τ_s	Social Security Tax	0.05
Mandatory Add-on	$kmin$	Minimum fixed contribution rate	0.03
Mandatory Carve-out	k_c	Mandatory Carve-out rate	0.03

Table 2: Life-Cycle Properties

	Voluntary Add-on/ Benchmark Model	Mandatory Add-on	Mandatory Carve Out
	Median Wealth-Income Ratios in the TA (W_t/Y_t^{net})		
Age			
<36	0.84	0.84	0.87
36 -50	1.54	1.82	2
51-65	2.81	3.01	3.39
	Median Wealth-Income Ratios in the TDA (W_r/Y_t^{net})		
Age			
<36	0.07	0.29	0.3
36 -50	1.4	1.34	1.42
51-65	4.99	5.02	5.29
	Fraction of portfolio invested in stocks in the TA (α_t^τ)		
Age			
<36	0.8	0.88	0.89
36 -50	1	1	1
51-65	0.96	0.97	0.95
	Fraction of portfolio invested in stocks in the TDA (α_t^τ)		
Age			
<36	1	0.97	0.99
36 -50	0.91	0.85	0.84
51-65	0.53	0.51	0.46
	Average contribution rate to TDA (k) in $\%$ of Y_t^{net}		
Age			
<36	2.24	5.17	5.54
36 -50	7.16	6.51	6.75
51-65	8.26	10.1	12.41
	Median welfare loss compared to the benchmark scenario in $\%$		
Age 21		3	-1.01

Table 3: Voluntary carve-out depending on age at carve-out

Quartiles of Wealth-Income Ratios in the TA (W_t/Y_t^{net})						
	Q I Interval	Q II Interval	QIII Interval	QIV Interval	Total	Carve-out rate in %
Age 20	0.18- 0.29	0.29 - 0.32	0.32 - 0.35	0.35 - 0.56		
No. of households carving out	0	0	0	1	1	0
Age 45	0.91 - 1.96	1.96 - 2.36	2.36 - 2.83	2.83 - 8.28		
No. of households carving out	6250	6250	6245	6098	24843	99
Age 60	0.73 - 2.46	2.46 - 3.52	3.52 - 5.04	5.04 - 17.21		
No. of households carving out	6250	6249	6251	6250	25000	100

Table 4: Results across different income profiles

	Voluntary Add-on (Benchmark Model)			Mandatory Add-on			Mandatory Carve Out		
	LHS	HS	CD	LHS	HS	CD	LHS	HS	CD
Median Wealth-Income Ratios in the TA (W_t/Y_t^{net})									
Age									
<36	1.1	0.92	0.84	1.34	0.92	0.85	1.72	0.92	0.87
36 -50	3.38	2.24	1.54	3.49	2.36	1.82	3.33	2.68	2
51-65	4.16	2.67	2.81	4.25	2.73	3.01	4.62	2.94	3.39
Median Wealth-Income Ratios in the TDA (W_r/Y_t^{net})									
Age									
<36	0.64	0.43	0.07	0.48	0.37	0.29	0.5	0.44	0.3
36 -50	1.97	1.68	1.4	1.86	1.58	1.34	2	1.85	1.42
51-65	5.74	5.11	4.99	5.77	5.1	5.02	5.99	5.37	5.29
Fraction of portfolio invested in stocks in the TA (α_t^τ)									
Age									
<36	1	0.99	0.8	1	0.99	0.88	1	1	0.89
36 -50	0.99	1	1	0.98	1	1	0.99	1	1
51-65	0.95	0.97	0.96	0.94	0.96	0.97	0.96	0.97	0.95
Fraction of portfolio invested in stocks in the TDA (α_t^τ)									
Age									
<36	0.96	0.98	1	0.99	1	0.97	0.99	0.98	0.99
36 -50	0.67	0.85	0.91	0.61	0.8	0.85	0.65	0.81	0.84
51-65	0.43	0.58	0.53	0.42	0.57	0.51	0.44	0.6	0.46
Average contribution rate to TDA (k) in % of Y_t^{net}									
Age									
<36	5.54	4.73	2.24	5.15	4.54	5.17	5.99	5.98	5.54
36 -50	3.83	4.84	7.16	5.66	6.21	6.51	6.65	6.81	6.75
51-65	8.15	6.1	8.26	9.72	7.88	10.1	9.44	10.6	12.41
Median welfare loss compared to the benchmark scenario in %									
Age 21				6.18	6.4	2.8	-0.55	-0.90	-1.01

Table 5: Default Portfolio Rules

	Voluntary Add-on (Benchmark Model)			Mandatory Add-on			Mandatory Carve Out		
	Endogenous α_r	$1/n$ rule	$(100-age)\%$ rule	Endogenous α_r	$1/n$ rule	$(100-age)\%$ rule	Endogenous α_r	$1/n$ rule	$(100-age)\%$ rule
Median Wealth-Income Ratios in the TA (W_t/Y_t^{net})									
Age									
<36	0.84	0.84	0.84	0.85	0.84	0.84	0.87	0.87	0.87
36 -50	1.54	1.56	1.55	1.82	1.83	1.82	2	2.03	2.01
51-65	2.81	2.78	2.75	3.01	3.02	3	3.39	3.46	3.4
Median Wealth-Income Ratios in the TDA (W_r/Y_t^{net})									
Age									
<36	0.07	0.07	0.07	0.29	0.28	0.29	0.3	0.29	0.3
36 -50	1.4	1.31	1.37	1.34	1.2	1.26	1.42	1.25	1.31
51-65	4.99	4.64	4.67	5.02	4.6	4.68	5.29	4.85	4.98
Fraction of portfolio invested in stocks in the TA (α_t^r)									
Age									
<36	0.8	0.86	0.86	0.88	0.89	0.89	0.89	0.89	0.89
36 -50	1	1	1	1	1	1	1	1	1
51-65	0.96	0.97	0.99	0.97	0.97	0.99	0.97	0.94	0.97
Fraction of portfolio invested in stocks in the TDA (α_t^r)									
Age									
<36	1	0.500	0.72	0.97	0.500	0.72	0.99	0.500	0.72
36 -50	0.91	0.500	0.57	0.85	0.500	0.57	0.84	0.500	0.57
51-65	0.53	0.500	0.42	0.51	0.500	0.42	0.46 0.500	0.42	
Average contribution rate to TDA (k) of Y_t^{net}									
Age									
<36	0.02	0.03	0.03	0.05	0.05	0.05	0.06	0.06	0.06
36 -50	0.07	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07
51-65	0.08	0.09	0.06	0.1	0.1	0.11	0.12	0.13	0.11
Median welfare loss compared to the same model scenario with endogenous α_t^r in $\%$									
Age 21		0.2	0.02		0.32	0.15		0.49	0.54

Table 6: Uncertain Retirement Income

	Per-period Probability of a reform		Disastrous Income Draw at Age 64	
	Prob = 0.3 in each t	Prob = 0.5 in each t	Prob = 0.5 $\underline{Y} = 0.5\bar{Y}$	Prob = 0.5 $\underline{Y} = 0.25\bar{Y}$
	Median Wealth-Income Ratios in the TA (W_t/Y_t^{net})			
Age				
<36	0.85	1.16	0.93	0.9
36 -50	1.93	2.05	2.16	1.98
51-65	3.26	3.84	3.93	3.31
	Median Wealth-Income Ratios in the TDA (W_r/Y_t^{net})			
Age				
<36	0.19	0.56	0.14	0.10
36 -50	1.29	1.67	1.6	1.41
51-65	4.99	5.46	5.38	4.67
	Fraction of portfolio invested in stocks in the TA (α_t^τ)			
Age				
<36	0.82	0.80	0.84	0.86
36 -50	1	0.99	1	0.97
51-65	0.83	0.85	0.94	0.90
	Fraction of portfolio invested in stocks in the TDA (α_t^r)			
Age				
<36	1	1	1	1
36 -50	0.8	0.96	0.84	0.85
51-65	0.63	0.68	0.44	0.57
	Average contribution rate to TDA (k) of Y_t^{net}			
Age				
<36	4.65	5.11	5.28	4.32
36 -50	6.62	7.12	6.1	5.99
51-65	11.49	11.40	10.59	9.57
	Median Welfare Loss compared to benchmark			
Age				
21	1.872	3.4871	0.325	1.4755

Figure 1: Income Profiles of Different Education Levels