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Optimal savings for retirement: the role of individual accounts and disaster expectations

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Abstract:
We employ a life-cycle model with income risk to analyze how tax-deferred individual accounts affect households' savings for retirement. We consider voluntary accounts as opposed to mandatory accounts with minimum contribution rates. We contrast add-on accounts with carve-out accounts that partly replace social security contributions. Quantitative results suggest that making add-on accounts mandatory has adverse welfare effects across income groups. Carve-out accounts generate welfare gains for high and middle income earners but welfare losses for low income earners. In the presence of rare stock market disasters, individual accounts with default portfolio allocation crowd out direct stockholding and substantially reduce welfare.

Keywords:
Individual retirement accounts, household portfolio choice, consumption and saving over the life-cycle

JEL-Classification:
E21, H55, G11.

Non-technical summary

Tax-deferred individual retirement accounts have become an increasingly important component of the social security systems worldwide. However, the role that individual accounts assume with respect to the public retirement system varies substantially across countries. Voluntary and mandatory add-on accounts supplement the public pension system while carve-out accounts replace part or all of the unfunded pension system with funded individual accounts. The current discussion on pension reform in the U.S. centers around the question which form such plans should take in the public pension system.

Using a life-cycle model calibrated to the U.S., we vary the roles individual retirement accounts assume in the public social security system and examine the effects on households' consumption and savings decisions depending on the type of account implemented. To take account of the investment risks that plan participants face, we also study the effects of default investment rules in the retirement account and the impact of a stock market crash on households' retirement savings, their portfolio choice and welfare.

Our results show that if households are required to hold mandatory add-on accounts with a compulsory minimum contribution rate, they are forced to invest more for retirement in younger years when they would rather consume than save. Crowding out retirement savings that households would voluntarily undertake at later stages in life generates welfare losses of between 2 and 3 % of certainty-equivalent consumption across different income groups. On the contrary, carve-out accounts have a positive impact on welfare for middle and high income earners because of the benefits of converting social security contributions into individually managed accounts with optimally chosen risky portfolio shares. For the low income group, however, mandatory carve-out accounts generate welfare losses because low income earners face limited benefits from the tax deferral and do not save sufficiently to compensate for future income reductions.

The perceived risk of a financial market downturn affects the optimal portfolio choices substantially. While in normal times default portfolio rules have limited welfare effects, they imply higher utility costs in the presence of rare stock market disasters as they crowd out direct stock market participation. This finding is important given that many households may not be able to make informed investment decisions. Default investment rules can be considered as a device to limit the potential welfare costs generated by major investment mistakes for the financially less literate.

Nicht-technische Zusammenfassung

Steuerlich begünstigte persönliche Rentenkonten spielen weltweit eine immer größere Rolle innerhalb der Sozialversicherungssysteme. Allerdings variiert die Bedeutung und Ausgestaltung, die diesen persönlichen Konten im jeweiligen staatlichen Altersversorgungssystem zukommt, von Land zu Land erheblich. Freiwillige und obligatorische Zusatzkonten stellen Ergänzungen zur staatlichen Alterssicherung dar, während im Fall von Rentenkonten, die Rentenversicherungsbeiträge abzweigen (sog. "carve-out accounts"), das nicht kapitalgedeckte Altersversorgungssystem zum Teil oder zur Gänze durch kapitalgedeckte persönliche Konten ersetzt wird. Die aktuelle Diskussion zur Rentenreform in den Vereinigten Staaten kreist um die Frage, wie diese verschiedenen Formen der Alterssicherung in das staatliche System eingebracht werden sollen.

Anhand eines auf die USA kalibrierten Lebenszyklusmodells wird die jeweilige Bedeutung persönlicher Rentenkonten im staatlichen Sozialversicherungssystem variiert, und es wird untersucht, wie sich unterschiedliche Rentenkontentypen auf die Konsum- und Sparentscheidungen der privaten Haushalte auswirken. Bei der Berücksichtigung der Anlagerisiken, denen die Beitragszahler bei dieser Form der privaten Altersvorsorge ausgesetzt sind, wurden auch die Auswirkungen von einfachen, deterministischen Anlageregeln beleuchtet, und es wurde der Frage nachgegangen, welchen Effekt die Erwartung eines gravierenden Einbruchs der Aktienpreise (Börsenkrach) auf die Ersparnisse zur Altersvorsorge, die Anlageentscheidungen und die Wohlfahrt der privaten Haushalte hätte.

Die Studie zeigt, dass private Haushalte, die ein obligatorisches Zusatzkonto mit einem vorgeschriebenen Mindestbeitrag unterhalten müssen, in jüngeren Jahren- und somit zu einer Zeit, in der ihre Konsumneigung in der Regel höher ist als ihre Sparneigung- gezwungen sind, mehr in die Altersversorgung zu investieren als sie optimal wünschen. Die Verdrängung von Ersparnissen zur Altersvorsorge, welche die privaten Haushalte in späteren Lebensphasen freiwillig tätigen würden, führt in den verschiedenen Einkommensgruppen zu Wohlfahrtsverlusten von 2% bis 3%, gemessen als Gewissheitsäquivalent des Konsums. Im Gegensatz dazu wirken sich "carve-out"-Konten positiv auf die Wohlfahrt der Bezieher mittlerer und hoher Einkommen aus, da die Umwandlung von Sozialversicherungsbeiträgen in individuell verwaltete Konten mit einer optimalen Verteilung risikohaltiger Portfoliokomponenten Vorteile mit sich bringt. In der einkommensschwachen Gruppe führen obligatorische "carve-out"-Konten allerdings zu Wohlfahrtsverlusten, da die Betroffenen von der Steuerbegünstigung nur bedingt profitieren und keine ausreichend hohen Ersparnisse anlegen, um künftige Einkommenseinbußen aufzufangen.

Wenn das Risiko einer Finanzmarktkrise in die Erwartungen der Haushalte mit eingeht, werden optimale Portfolioentscheidungen durch obligatorische Anlageregeln erheblich beeinträchtigt. Während feste Portfolio-Anlageregeln unter normalen Umständen begrenzte Wohlfahrtseffekte haben, implizieren sie, wenn selten auftretende Börsenkräche in Betracht gezogen werden, höhere Einbußen im Nutzen der Haushalte, da sie eine direkte Beteiligung am Aktienmarkt verdrängen. Dieses Ergebnis ist angesichts der Tatsache, dass viele private Haushalte möglicherweise nicht in der Lage sind, fundierte Anlageentscheidungen zu treffen, von Bedeutung. Feste Anlageregeln können als ein Instrument fungieren, mit welchem sich potenzielle Wohlfahrtsverluste, die durch umfangreiche Anlagefehlentscheidungen seitens in Finanzdingen weniger versierter Personen entstehen, begrenzen lassen.

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1 Introduction

In many countries tax-deferred individual accounts have become an increasingly important component of the social security system. Around the world, different pension systems feature different types of defined contribution plans. While in the U.S. IRAs or 401(k) plans are voluntary, other countries such as Sweden, Denmark and Australia recently introduced individual accounts that require compulsory contributions that co-exist with the unfunded public pension system. In contrast, in the UK and Japan, households can decide whether they contribute to the public retirement system or whether they "contract-out" into approved personal pension plans that fully or partially replace social security contributions. Since in 2001 the President's Commission suggested to include mandatory individual accounts in the social security system, there has been an ongoing policy debate on the role of individual accounts in the U.S. pension system.[2] In view of the recent financial turmoil, it has become particularly important to understand the influence of stock market crashes on households' retirement savings, their portfolio choice, and the role of individual accounts.[3]

This paper employs a life-cycle model with exogenous stochastic labor income calibrated to the U.S. to analyze how different types of tax-deferred individual accounts affect households' consumption, savings and portfolio allocation decisions as well as welfare. We incorporate the risk of losing retirement benefits due to a financial market downturn and analyze the impact of disaster expectations on optimal retirement savings in individual accounts.[4]

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[1]Previous versions of this paper were circulated under the title 'Pension Reform and Individual Accounts'. We thank Michael Haliassos, seminar participants at the Deutsche Bundesbank, participants at the International Netspar Pension Workshop 2011, the Meeting of the Canadian Economic Association 2010 and the Meetings of the European Economic Association 2009 for very useful comments and suggestions. The views expressed by the authors in this paper are their own and do not necessarily reflect those of the Deutsche Bundesbank.
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[2]See President's Commission to Strengthen Social Security (2001) and Geanakoplos and Zeldes (2009).

[3]See the papers on retirement plans and the Great Recession in the May 2011 edition of The American Economic Review.

[4]In a recent paper, Alan (2011) shows that the perceived risk of a stock market disaster significantly reduces stock market participation and stockholding in a life-cycle model. Her model, however, abstracts

Our life-cycle model of portfolio choice builds on Gomes, Michaelides, and Polkovnichenko (2009) and Dammon, Spatt, and Zhang (2004) and assumes that households can save in a taxable as well as an illiquid, tax-deferred account. In line with the literature on limited stock holding, in order to hold risky assets in the taxable account households need to pay a one-time fixed stock market entry fee. In contrast, investing in stocks is costless in the tax-deferred account. We follow the categorization of Turner (2006) and consider three different types of individual accounts. First, as in Gomes et al. (2009), households can save voluntarily in the individual account. Second, households are required to make compulsory minimum contributions to the individual account on top of their contributions to the public defined-benefit retirement system. Third, households carve out into mandatory individual accounts that replace part of the public social security system. In this scenario, households get a rebate on their contributions to the public pension system but are required to invest that amount in the funded individual account. Following Alan (2011) we introduce disaster expectations by assuming that households face a small probability of experiencing a stock market crash in each period when they update their expectations. We use the estimated disaster probabilities and stock market drops for the U.S. by Barro and Ursua (2008) and analyze the effects of the perceived risk of a financial market downturn on retirement savings considering the different types of individual accounts.

Our quantitative results show that households save in voluntary individual accounts for two reasons. First, taxation is deferred, i.e., taxes are paid upon withdrawal, and, second, the retirement account provides costless access to risky assets yielding a risk premium. On the other hand, retirement accounts are illiquid, and in our model households cannot withdraw funds until retirement age. In line with Gomes et al. (2009) and Pries (2007) our simulation results show that early in life households save little in the illiquid account but from age 35 the contributions to the individual account start to rise such that retirement wealth follows a hump shape over the life cycle. The perceived risk of a financial market downturn affects optimal savings and portfolio choices substantially: households strongly reduce their stock market exposure in the taxable, liquid account and reduce their contributions to the illiquid individual account.

If households are required to hold mandatory add-on accounts with a compulsory minimum contribution rate, they are forced to invest more for retirement in younger years when they would rather consume than save. Crowding out retirement savings that households would voluntarily undertake at later stages in life generates welfare losses of

from tax-deferred individual accounts.

between 2 and 3 % of certainty-equivalent consumption across different income groups. Comparing add-on and carve-out accounts reveals that the latter generate higher savings in the individual account as well as in the liquid taxable account due to the positive income effect of the rebate on the social security contributions. In retirement, when households have lower income from the public pension system, they use their private retirement wealth to compensate for the loss. Our analysis suggests that carve-out accounts have a positive impact on welfare for middle and high income earners because of the benefits of converting social security contributions into individually managed accounts with optimally chosen risky portfolio shares. For the low income group, however, mandatory carve-out accounts generate welfare losses because low income earners face limited benefits from the tax deferral and do not save sufficiently to compensate for future income reductions.

The worldwide trend toward defined contribution plans for retirement has raised concerns about the quality of the investment decisions of plan participants. In individual accounts, households may be subject to investment mistakes such as insufficient diversification, excessive trading or holding too much or too little risk.[5] In this context, in addition to default enrollment[6] and contribution rate schedules,[7] plans with default portfolio allocation rules have been put forward, see, e.g., Bodie and Treussard (2007), Viceira (2007), and Porterba, Rau, Venti, and Wise (2010). We employ our calibrated life-cycle model to assess the quantitative impact of individual accounts with default portfolio allocation rules on consumption and wealth and verify the resulting utility costs. Clearly, default investment rules generate welfare losses as they impose a constraint on the optimal behavior of households. The question at hand is how harmful such a constraint is. As long as the welfare loss stemming from the non-optimality of default funds is lower than the welfare loss stemming from investment mistakes, policymakers may find it worthwhile to consider portfolio rules. Our quantitative results suggest that while default portfolio rules have hardly any effect on households' wealth accumulation in the absence of the probability of a stock market crash, they strongly affect households' investment choices when we allow for disaster expectations. In a world with rare stock market disasters, default portfolio rules crowd out direct stockholding and generate welfare losses of approximately

[5]Survey-based evidence on households' financial capabilities shows that a consistent fraction of the population lacks basic financial knowledge. Studies that focus on the quality of the investment decisions are, e.g., Lusardi and Mitchell (2011), Lusardi and Mitchell (2007), Calvet, Campbell, and Sodini (2007), Turner (2006), Thaler and Bernartzi (2004), Bernartzi and Thaler (2001) and Agnew, Balduzzi, and Sunden (2003).

[6]See, e.g., Carroll, Choi, Laibson, Madrian, and Metrick (2009), Bernartzi and Thaler (2007), Choi, Laibson, Madrian, and Metrick (2004), Choi, Laibson, Madrian, and Metrick (2002) and Madrian and Shea (2001) who propose automatic enrollment policies with an option to opt-out.

[7]See, e.g., Thaler and Bernartzi (2004) and Pries (2007).

1.5 % of certainty-equivalent consumption since households have to take more risk in their individual accounts than they optimally desire.

Our paper contributes to the literature by analyzing pension reforms and optimal individual behavior in a realistically calibrated life-cycle model of portfolio choice with exogenous stochastic labor income. We build on Gomes et al. (2009), Dammon et al. (2004), Amromin (2003) and Love (2007) who study the tax-efficient asset location and allocation decisions with taxable and tax-deferred accounts. In these papers, the effects of different types of individual accounts are not taken into account. Our paper is also related to Campbell, Cocco, Gomes, and Maenhout (2001) who analyze the effects of alternative retirement systems on consumption, wealth accumulation and portfolio choice in a partial equilibrium model. However, they do not explicitly model tax-deferred savings accounts. Pries (2007) introduces different personal retirement accounts in a life-cycle model but focuses mainly on labor supply distortions over the lifetime. These papers all abstract from the risk of losing retirement savings due to a financial market downturn.

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), De Nardi, Imrohoroglu, and Sargent (1999) and Menil, Murtin, and Sheshinski (2006). Given their emphasis on general equilibrium phenomena, these papers often make simplifying assumptions about the actual decision problems that individuals face, in particular with respect to stockholding decisions.

The paper is structured as follows. Section 2 discusses individual retirement accounts in different countries. In section 3 we present the life-cycle model of optimal portfolio choice with different types of tax-deferred individual accounts. Section 4 describes the calibration of the model and presents the quantitative findings. Finally, section 5 concludes.

2 Individual Accounts Around the World

There is a common trend in public pension systems around the world: the number of defined benefit plans is declining while defined contribution plans have become increasingly important. Individual accounts take a number of forms in different retirement systems. Turner (2006) and Kritzer (2005) note that the choice depends on the country's cultural, economic and demographic background. Voluntary defined contribution plans have grown in importance in many high-income countries and can be found in, e.g., Canada, the UK, the U.S. as well as in Germany, Switzerland, Spain, Italy and the Scandinavian countries. Mandatory accounts were introduced by countries which had to fundamentally reform their pension structures and are now found in some Latin American countries but also in the reformed pension systems of Sweden, Denmark and Australia. Turner (2006) categorizes individual accounts according to their relationship to social security: they can be add-on accounts or carve-out accounts from social security. An add-on account supplements the social security benefit and leaves social security contributions unaffected. A carve-out account replaces part or all of the social security benefit with benefits coming from the carve-out account. Table 1 is taken from Turner (2006) and gives an overview over the variety of types of individual accounts in public pension systems of different countries.

In the U.S. there is an ongoing policy discussion on the role of individual accounts in the pension system, see Geanakoplos and Zeldes (2009), Turner (2006) and Kritzer (2005). Turner (2006) argues that the reformed social security systems of Sweden, the UK and Chile are the most likely ones to influence the design of a pension reform in the U.S. In 1999 Sweden reformed its defined-benefit social security system by introducing mandatory supplemental individual accounts. Out of the total contribution rate of 18.5% to the new pension system, 2.5% are diverted to individual accounts, the "Premium Pension". Swedish participants have a choice of more than 460 different funds to choose from with a default fund run by the government (Sunden (2006)). As early as 1980, Chile reformed its pay-as-you-go defined-benefit system by replacing it with privately managed individual accounts (full carve-out). Participants contribute 10% of their pre-tax salary and may also make voluntary contributions to a private pension fund of their choice. Contributions are tax-deductible so that the government subsidizes pensions. There are different funds participants can choose from with a default fund that invests according to the participant's age. Since 1986 the UK's pension system has included carve-out accounts that allow participants to voluntarily substitute a part of social security with an individual account. Employees can contract-out of the public defined-benefit plan into an Approved Personal Pension based on individual accounts. Participants of carve-out individual accounts receive a rebate on their social security contributions, which is paid directly into the carve-out account.

In the following, we develop a life-cycle model with exogenous stochastic labor income calibrated to the U.S. considering three different types of individual accounts.[8] First,

[8]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).

we consider the status quo of the U.S. and suppose that households can save voluntarily in the tax-deferred account. Second, we consider mandatory add-on accounts as they are implemented in Sweden. Third, as in the UK, households carve-out into mandatory individual accounts that partially replace the public social security system.

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 account.[9]

Households live for a maximum of T periods and face an exogenous conditional survival probability at each age t. Households' preferences are given by

$$E_0 \sum_{t=0}^{T} \beta^t \left(\Pi_{j=0}^{t} p_j\right) \frac{C_t^{1-\rho}}{1-\rho},$$

where C_t is consumption and ρ denotes the parameter of relative risk aversion. $0 < \beta < 1$ is the discount factor. p_j denotes the probability of being alive at age j, conditional on $j-1$.

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 $f(t, Z_t)$ is a deterministic function of age t and household characteristics Z_t. P_t denotes the permanent component of labor income. The logs of the transitory and permanent 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 σ_N^2, respectively. Retirement takes 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, during retirement households withdraw wealth from their tax-deferred account.

The investment opportunity set consists of two assets: households can invest in a riskless asset (bond) and in a risky asset (stock) in both the TA as well as in the illiquid

[9] In our model, we make the simplifying assumption that the TDA is completely illiquid during working life and households gain access to their retirement savings only as they retire. In reality, retirement accounts are de facto illiquid as withdrawals are subject to penalties and individuals gain access to TDAs as they reach a pre-specified age which does not have to coincide exactly with their entry into retirement. See Holden, Ireland, Leonard-Chambers, and Bogdan (2005) for details on the rules of TDAs in the U.S.

TDA. There is a risk premium on holding risky assets:

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

r_t^s and r^b are the returns on the risky and the safe asset, respectively. μ^s is the mean risk premium and ϵ_t^s is independent and identically normally distributed with mean 0 and variance σ_ϵ^2. Households pay taxes on returns in the taxable account, and $\tilde{r}^s$ denotes the after-tax return on the risky asset while $\tilde{r}^b$ is the after-tax return on the safe asset.

Households save in the illiquid TDA because investment in the TDA is exempt from labor income taxes and retirement assets are accumulated at pre-tax rates of return. In addition, stock market participation is costless in the TDA, while in the TA households have to pay fixed stock market entry costs that are, e.g., associated with the transaction cost of opening a brokerage account. As argued in section 2, 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 a 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 contributions. Moreover, we distinguish individual accounts by their degree of compulsion, i.e., whether participation in individual retirement accounts is voluntary or mandatory.

3.1 Add-On Tax-Deferred Accounts

As a benchmark scenario we consider voluntary add-on accounts as analyzed by Gomes et al. (2009). We assume that households can contribute a fraction of their income to the unfunded social security system and, in addition, save for retirement in the TDA. In both accounts, the household may invest in a riskless as well as in a risky asset. Let α_t^r and α_t^τ denote the share invested in risky assets in the retirement account and taxable account, respectively. During working life, wealth in the taxable account evolves according to

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

with the borrowing constraint $W_{t+1}^\tau \geq 0$ and the short-sell constraint $\alpha_t^\tau \in [0,1]$. τ_d and τ_s represent the labor income and social security tax, respectively. $\tilde{r}_{t+1}^s$ and $\tilde{r}^b$ are the after-tax returns on the risky and the safe asset, respectively. $k_t \in [0, 0.2]$ denotes the endogenous contribution rate to the individual retirement account that is exempt from labor income tax. F_t denotes the fixed entry cost as a share of 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, savings accumulate tax-free. During working life, wealth accumulation in the retirement account is given by

$$W_{t+1}^r = [\alpha_t^r(1 + r_{t+1}^s) + (1 - \alpha_t^r)(1 + r^b)](W_t^r + k_t Y_t) \tag{2}$$

with the borrowing constraint $W_{t+1}^r \geq 0$ and the short-sell constraint $\alpha_t^r \in [0, 1]$. r_{t+1}^s and r^b are untaxed returns as opposed to the after-tax returns $\tilde{r}_{t+1}^s$ and $\tilde{r}^b$ imposed in the TA.[10]

In retirement, both constraints change to take account of the fact that households receive income from the withdrawals Q_t of the TDA that are taxed with the labor income tax. During retirement, wealth accumulation in the TA is given by:

$$\begin{aligned} W_{t+1}^\tau = \quad & [\alpha_t^\tau(1 + \tilde{r}_{t+1}^s) + (1 - \alpha_t^\tau)(1 + \tilde{r}^b)](W_t^\tau - C_t + (1 - \tau_d)Q_t - I_t F_t P_t) \\ & +(1 - \tau_d)Y_{t+1}. \end{aligned} \tag{3}$$

In retirement, wealth in the TDA evolves according to

$$W_{t+1}^r = [\alpha_t^r(1 + r_{t+1}^s) + (1 - \alpha_t^r)(1 + r^b)](W_t^r - Q_t) \tag{4}$$

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 households' life expectancy A_t.[11]

We contrast 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. In this variation of the model, households face the additional constraint $k_t \geq k^{min}$ 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 pension system with individual accounts: households get a rebate on their social security contributions but are required to invest that amount in the TDA. The carve-out works like a

[10] In our model, there is no employer-matching, i.e., households only benefit from the tax-deferral of their own savings. Employer-matching, of course, makes saving in the TDA more beneficial as the employer matches the contribution of households one to one up to a certain cap.

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

"loan" from social security: the worker borrows from future social security benefits to invest in an individual tax-deferred retirement account. Workers repay the loan through receipt of reduced social security benefits (Turner (2006)). To take account of the reduction of future benefits, we calculate the accumulation of carved-out contributions, k^c, in a "hypothetical account" (HA) assuming an interest rate on the hypothetical balance equal to the risk-free rate.[12] 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. In carve-out accounts, employees benefit from the higher returns that they receive over the return to their contributions that social security would give them.

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

$$W_{t+1}^h = (1 + r^b)W_t^h + k^c P_t.$$

$k^c > 0$ denotes the constant and exogenous carved-out contribution rate from social security. Accordingly, retirement income is reduced by $\frac{W_t^h}{A_t}$ where A_t denotes the household's life expectancy at age t.

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

$$\begin{aligned} W_{t+1}^\tau = \quad & [\alpha_t^\tau(1 + \tilde{r}_{t+1}^s) + (1 - \alpha_t^\tau)(1 + \tilde{r}^b)](W_t^\tau - C_t - k_t Y_t(1 - \tau_d) - I_t F_t P_t) \\ & +(1 - \tau_d - \tau_s^*)Y_{t+1} \end{aligned} \tag{5}$$

with $k_t \geq k^c$, meaning that households have the opportunity to voluntarily save on top of the carved-out contributions. Since households divert part of their social security contributions k^c to the individual retirement account, the social security contributions are reduced to $\tau_s^* = \tau_s - k^c$.

During retirement, wealth accumulation in the taxable account is given by

$$W_{t+1}^\tau = [\alpha_t^\tau(1+\tilde{r}_{t+1}^s)+(1-\alpha_t^\tau)(1+\tilde{r}^b)](W_t^\tau - C_t + (1-\tau_d)Q_t - I_t F_t P_t) + (1-\tau_d)(Y_{t+1} - \frac{W_{t+1}^h}{A_{t+1}}). \tag{6}$$

[12]The trade-off between contributions to an individual carve-out account and the reduction in the future payout of social security is one of the most important aspects in the design of a carve-out account as it directly affects the generosity of the carve-out account for participants and the related costs to the government. The debate about the "right" interest rate for the benefit offset is also reflected by the report of the President's Commission (President's Commission to Strengthen Social Security (2001)) which includes three different possible rates. An interest rate in the hypothetical account below the risk free rate implies that the individual account is subsidized by the social security system. An interest rate equal to the bond rate means there is no subsidy, which is what we assume here.

During working life and retirement, wealth accumulation in the TDA is described by equations (2) and (4), respectively.

4 Quantitative Results

4.1 Calibration

To assess the quantitative properties of our life-cycle model we calibrate the model to the U.S. economy. Table 2 summarizes the parameter values for the benchmark model. We employ the estimated gross income profiles by Fehr, Jokisch, and Kotlikoff (2005) that are based on pre-tax non-financial income. Working life starts at age 20, retirement takes place exogenously at age 65, and the replacement rate is set to 60% which is in line with the empirical evidence for the U.S. (see Gomes et al. (2009)). Figure 1 displays the estimated income profile for three different income groups. The solid line is the middle income group which is used in the benchmark calibration. We set the variances of the permanent and temporary shocks to labor income to 10% which is in line with Carroll (1997).

We follow the household finance literature and set the parameter of relative risk aversion $\rho = 4$ and the discount rate $\beta = 0.96$. We assume a labor income tax equal to 25% which corresponds to the empirical average income tax of the middle income group. In the taxable account, the return on bonds is taxed at a rate equal to the labor income tax. In line with the U.S. tax system, the return on bonds is taxed higher than the return on stocks which we calibrate to 22.5%. Social security contributions for the defined-benefit system of the U.S. are at 6.5% and this is the rate at which we set the social security payroll tax in the model.[13]

The real bond return is set to 2 % and the mean equity premium equals 4% with a standard deviation of 20%. The correlation between stock returns and permanent labor income shocks is 0.15. There is no correlation between stock returns and the transitory labor income shocks. These parameter values are standard in the literature, see, e.g., Cocco, Gomes, and Maenhout (2005).

The size of the fixed stock market entry cost has been debated. While some authors find that it is negligible, others argue that it is necessary to match stockholding over the life cycle, see, e.g., Alan (2006) and Vissing-Jorgensen (2002). We follow Gomes et al. (2009) and set the one-time fixed cost to 5% of permanent income.

[13] We assume that all employees pay 6.5% of their gross wages as contributions, irrespective of their income, i.e. there is no upper limit on the wages subject to the social security contributions, such as the Social Security Wage Base.

We follow Alan (2011) and introduce disaster expectations by assuming that households face a small probability of experiencing a stock market disaster in each period when they update their expectations. If a disaster strikes, a large portion of the household's stock market wealth evaporates and households face a negative return of ϕ. We use the estimated disaster probabilities and stock market drops for the U.S. by Barro and Ursua (2008). The probability of a disaster for the U.S. is assumed to be 4.03% and the negative return in the case of a disaster is on average 27.8%.[14]

4.2 Voluntary Add-On Accounts

As a benchmark, we assume that households can voluntarily invest in tax-deferred individual accounts in addition to the social security contributions. We simulate the life-cycle patterns of consumption, savings in the liquid account, contributions to the individual account, the risky shares and the resulting cash on hand variables for 10,000 households. We calculate the mean contribution rates to the individual account, the mean risky shares as well as median wealth-to-earnings ratios in the taxable and the tax-deferred account across households and across age groups. To analyze the impact of the perceived risk of a financial downturn, the solid lines in figure 2 present the life-cycle patterns for the benchmark model without disaster expectations, while the solid lines in figure 3 refer to the model that incorporates the probability of a stock market crash.

If households save voluntarily in the tax-deferred individual account, wealth accumulation in the TDA and TA features a hump shape over the life cycle. Young households have a high expected future income against which they cannot borrow and they prefer to consume most of their income and save modestly for precautionary reasons. As labor income increases and the income profile becomes less steep, from about 30-35 years of age, the contribution rate k_t to the individual account starts to increase, and wealth accumulation in the retirement account rises fast due to the tax-deferral of returns. During the last years before retirement, agents save on average 5% of their annual gross income in their individual account. This is in line with the findings of Gomes et al. (2009).

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

[14] In principle, one can think of many implications that disasters might have in our model. For example, they might have effects on social security income λY_K, wage income Y_t and the bond return r^b. Our focus is on the risky portfolio location and allocation decisions in the TA and the TDA. We therefore abstract from any other influence of macroeconomic disasters and isolate the effects that a drop in the stock return has on portfolio choice and tax-efficient behavior. Introducing such additional features of a recession would, however, be easy to implement. In our model, any further uncertainty driven by a recession would lead to additional background risk and higher bond holdings.

accumulated sufficient wealth. This happens quickly in the first few years after which they pay the fixed entry cost. The direct participation rate in the stock market reaches 100% by the age of 30. Conditional on stock market participation, young households allocate almost all of their assets to stocks in the TA. 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 households grow older and their permanent income decreases, they reduce their exposure to stocks and start investing in bonds.[15] Since households do not need to pay a fixed entry cost to hold stocks in the TDA, they invest almost fully in stocks early in life. As investors grow older, however, they increasingly shift their TDA portfolios towards bonds, the higher-taxed security, to optimize tax-allocation of their assets. 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 in both accounts as the end of life approaches.[16]

Figure 3 shows that introducing a small probability of a financial market downturn affects the optimal portfolio choices substantially. During working life, households are subject to risky labor income and - in addition - face the risk of a stock market crash. Households save a large fraction of their TA wealth in stocks only at the beginning of their lives and reduce their stock market exposure quickly as they age. The decrease in the risky portfolio share is modest in the TDA as the effect of the stock market risk will only affect households after retirement when they have certain labor income. However, the increased stock market risk reduces savings in the illiquid individual account.

4.3 Mandatory Add-On Accounts

In this section we assume that households are required to save a compulsory contribution rate to an individual account in addition to the social security contributions. 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 and other countries. Households can still save more in a tax-deferred account voluntarily. The dashed lines in figures 2 and 3 refer to the life-cycle patterns for the model without and with disaster expectations, respectively.

Comparing wealth-to-income ratios over the life cycle with those of the voluntary add-

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

[16] This is due to the absence of a bequest motive in the model. Introducing bequests would lower shares towards the end of life.

on case reveals that households who have to save for retirement in a mandatory account at young ages consequently save less of their resources in the liquid, taxable account which drives the wealth-to-income ratios down. Compared to the benchmark model with voluntary add-on accounts, the introduction of minimum fixed contribution rates leads to higher median wealth-to-income ratios in the TDA during all ages. Voluntary contributions to the TDA above the mandatory contributions at later ages are "crowded-out". While households with a voluntary add-on account make very small contributions in younger ages and increase their retirement savings from age 35 onwards, households with mandatory add-on accounts have to invest 3% of their annual gross labor income for retirement from the beginning of their working lives when they would rather consume and save less in the tax-deferred account during the prime years of retirement saving.

While portfolio choices in the liquid account are hardly affected by the mandatory contributions to the individual account, households shift their TDA portfolios towards the safer asset. Households invest a substantial share in risky assets in the TDA only at older ages. The higher wealth-income ratios in the TDA and the optimal tax-allocation of assets induce households to invest their retirement savings in bonds. This effect is particularly strong if households face the additional risk of a stock market disaster, see figure 3.

To evaluate the welfare consequences of mandatory add-on accounts, we facilitate a comparison with voluntary accounts by calculating the constant consumption stream that makes the household as well-off in terms of expected utility.[17] Table 4 displays the welfare losses calculated in terms of percentage deviations in certainty-equivalent consumption relative to the voluntary add-on scenario if there is no disaster probability. Households living in the mandatory-add-on world suffer losses equal to 2.3 % of certainty-equivalent consumption, reflecting the adverse effects of compulsory savings for retirement in young years when they would prefer to consume more.

Table 5 shows that the presence of rare stock market disasters decreases the welfare loss generated by a mandatory add-on account. This is due to the tax-efficient behavior that characterizes optimizing households. In the presence of a disaster probability, households face increased background risk. Consequently, if individual accounts are voluntary, households reduce their contributions to the retirement account and shift their savings to the liquid account. If, however, individual accounts are mandatory, households cannot reduce their contributions and, instead, limit their risk exposure in the TDA by shifting their tax-deferred savings into bonds. As bond returns are taxed higher than stock re-

[17]Details are provided in the appendix.

turns, agents with mandatory add-on accounts choose a more tax-efficient allocation if they face the additional risk of losing retirement savings due to a stock market crash.

4.4 Mandatory Carve-Out Accounts

The mandatory carve-out accounts have two effects. First, they increase households' net income by giving them a rebate on their social security contributions, and, second, households have to invest the carved-out amount in the tax-deferred account. In retirement, their income from the unfunded public system is reduced by the annuitized amount to which their carve-out saving rate would have accumulated if invested at the risk-free rate.

The dotted lines in figures 2 and 3 show the life-cycle patterns associated with mandatory carve-out accounts without and with the additional risk of a financial market downturn, respectively. A comparison of the carve-out and the add-on scenarios reveals that the mandatory carve-out account generates higher savings in both the individual account as well as the liquid taxable account until agents are in retirement. This is due to the tax savings they encounter: households benefit from a positive income effect because of the reduced social security contributions. This results in higher consumption levels during working life compared to the voluntary add-on scenario. When households retire, they have accumulated more wealth in the individual account compared to the other two scenarios. Their higher private retirement wealth compensates for the loss in public pension benefits.[18]

Our welfare analysis in table 4 suggests that carve-out accounts have a positive impact on the welfare of middle income earners because of the benefits of converting social security contributions into individually managed tax-deferred accounts with optimally chosen risky portfolio shares. It turns out that households experience a welfare gain of 0.87 % of certainty-equivalent consumption relative to the voluntary add-on scenario. These gains are even larger if agents live in a world with disaster expectations, see table 5.

4.5 Default Portfolio Rules

The worldwide trend toward individual accounts in which investment decisions are made by the plan participants themselves has raised concerns about the quality of the investment decisions. Many authors have pointed out the lack of financial sophistication that results in low participation rates, inertia in portfolio choices and limited diversification, see, e.g., Lusardi and Mitchell (2011), Lusardi and Mitchell (2007), Turner (2006), Thaler and

[18]After deducting their carved-out contributions from the public pension benefits, their replacement rate amounts to 37% instead of 60% of their last working life income.

Bernartzi (2004), Bernartzi and Thaler (2001) and Calvet et al. (2007). In a large panel on 401(k) participants, Agnew et al. (2003) find that most asset allocations by TDA members are extreme (either 0 or 100 percent in equities) and that there is substantial inertia in asset allocations. Since investment mistakes may imply considerable welfare costs, default portfolio allocation rules (also known as life-cycle funds) have been put forward in the context of DC pension plans, see, e.g., Bodie and Treussard (2007), Viceira (2007), and Porterba et al. (2010). Such default portfolio allocations are typically inversely related to the participants' age, although other types of default funds exist.[19]

In our model, default investment rules generate welfare losses as they impose a constraint on the optimal behavior of households. The objective of this section is to analyze how harmful such a constraint is. As long as the welfare loss stemming from the non-optimality of default funds is lower than the welfare loss stemming from investment mistakes, policymakers may find it worthwhile to consider portfolio rules. Gomes, Kotlikoff, and Viceira (2008) calculate the welfare costs of employing different types of default investment rules in a model with flexible labor supply. They show that a typical life-cycle fund generates minimal deviations in consumption and wealth accumulation when compared to the optimal choices so that welfare losses are moderate. In the following, we pursue a similar analysis to evaluate the welfare costs of default rules in different types of individual accounts emphasizing the role of disaster expectations.

We study the effects of an age-dependent default portfolio allocation rule on households' savings decisions considering voluntary and mandatory add-on accounts as well as mandatory carve-out plans. The default rule fixes the risky share in the TDA, thereby exogenously mimicking a life-cycle fund where the risky share is falling as the participant gets older, $\alpha_t^r = (100 - age)\%$. Figures 4 and 5 show the life-cycle patterns associated with default rules in individual accounts without and with the additional risk of a financial market downturn, respectively.

If households do not face the risk of a financial market downturn, life-cycle patterns differ only slightly compared to the case of the optimally chosen risky shares. Only when they are old do agents hold higher risky shares in the TA as the default risky share is very low in the TDA. As a result, as table 4 shows, default portfolio rules generate rather modest welfare losses of approximately 0.20 % of certainty-equivalent consumption relative to the scenario of a voluntary add-on account with endogenous portfolio choice. These findings support the notion that it is beneficial to introduce default rules if the quality of investment decisions is low.

[19] See Viceira (2007) and the references in Bodie, McLeavey, and Siegel (2007).

While default portfolio rules have hardly any effect on households' wealth accumulation and portfolio choice for the liquid account in the absence of the probability of a stock market crash, they affect households' investment choice strongly and generate substantial welfare losses when we allow for disaster expectations. Figure 5 displays life-cycle profiles for households in the case of a default rule in the TDA in the presence of a small probability of a stock market disaster. Households that are forced to save in stocks through an age-dependent investment rule face an increased stock market risk in their retirement savings. The only way to reduce the exposure to stock market risk is to hold no stocks in the liquid account anymore. This is the case for the voluntary and mandatory add-on scenarios as well as the carve-out account. Households shift their liquid savings exclusively to bonds during their working years. Only during retirement, when they do not face labor risk anymore, they start investing in stocks in the liquid account. Overall, the effect is stronger for the case of a mandatory than for a voluntary individual account where households can still adjust their contribution rates downwards. These results support the empirical finding of limited direct stock market participation.

The welfare analysis in table 5 reveals that the combined scenario of default rules and disaster probabilities generates substantial welfare losses compared to the voluntary add-on account without the default rule. Households suffer welfare losses of 3.6% of certainty-equivalent consumption if they have to save in a mandatory add-on account. Even mandatory carve-out accounts generate welfare losses of 0.52 %. Thus, the negative effects of the high stock market risk dominate and make voluntary add-on accounts more attractive than mandatory carve-out accounts.

4.6 Different Income Groups

In many countries, the introduction of tax-deferred retirement plans is motivated by the envisaged advantages that low and middle income earners gain from such public policy. For example, low income earners are often less financially literate, and offering retirement savings plans may enable these households to benefit from the equity premium through low-cost participation in the stock market. Existing default rules can have additional positive effects as less financially educated households might be particularly prone to investment mistakes in terms of non-participation and under-diversification. We therefore solve and simulate our model for the optimal behavior of high and low income groups that can be identified with our income profile.[20]

[20] In our calibration, low, middle and high income groups only differ by their income levels and the diverse tax rates paid on these. Realistically calibrated income shocks should be different for different education groups, see, e.g., Cocco et al. (2005). Including different transitory and permanent shocks

In accordance with the tax brackets of the U.S. and other countries, higher income earners pay higher taxes compared to lower income groups. Table 3 displays the average tax rates that are paid by the high and low income groups as they are observed in the U.S. in 2001. Figure 5 shows the life-cycle patterns of the TDA contribution rates and of consumption (normalized by permanent income) for the different income groups. Table 4 shows the associated welfare effects arising from access to the different types of TDAs in the absence of rare stock market disasters.

Households in the highest income group have the strongest incentive to participate in the TDA as they benefit the most from the tax deferral. As a result, they start saving early for retirement and their contribution rates to the TDA increase quickly. In comparison to the voluntary add-on account, carve-out accounts generate substantial welfare gains of around 2 % for the high income earners. Mandatory add-on accounts still generate welfare losses, however, the adverse welfare effects are reduced in comparison to the middle income group. The same results hold if we account for disaster expectations, see table 5. These results underline the observation from micro data that mostly high income earners with higher income tax rates have the largest incentives to save in TDAs.

Households in the lowest income group pay a low tax rate on their gross income. As they benefit less from the tax-deferral of individual accounts, they encounter the highest welfare losses when saving for retirement is mandatory. Relative to voluntary add-on accounts, mandatory carve-out accounts imply utility costs for the low income earners while they generate utility gains for the middle and high income groups. To gain an intuition for this result, recall that during working life households holding a mandatory carve-out account get a rebate on their social security contributions while during retirement their income from the public pension is reduced. Since households invest a share α_t^r of their retirement savings in risky assets at the return r^s, whereas the hypothetical account accumulates at the lower safe return r^b, the loss in income from the public pension is at least compensated by the privately accumulated assets. Figure 5 shows that across all income groups, households save exactly $k_t = k^c$ in the carve-out account, i.e., they do not make higher contributions to the TDA than they have to until they are close to retirement. In contrast, if households invest in voluntary add-on accounts, they increase their contribution rates over the life-cycle. At the same time, during working life,

would leave our results qualitatively unchanged. There would be slight quantitative differences: including higher transitory and permanent shocks for low-income households would lead to higher uncertainty and therefore a more prudent portfolio choice and lower consumption, while a higher permanent shock for the high income group would make the high income group only slightly worse off in comparison to our results. Abstracting from different shocks allows us to focus on the tax incentives of the different income groups.

households with a carve-out account benefit from a positive income effect and consume more than households with an add-on account. Thus, part of the additional income during working life is consumed instead of saved as households discount the future. By the time of retirement, households decumulate their TDA wealth quickly as income from the public pension system is reduced. As a result, consumption normalized by permanent income is lower during retirement if households hold a carve-out account instead of an add-on account. The welfare analysis shown in tables 4 and 5 reveals that for the middle and high income groups the positive effects coming from the rebate on social security contributions as well as from the tax-deferral and risk premium dominate. Low income earners, however, suffer a utility cost of up to 0.50 % as they face a high marginal utility of consumption during working life and do not save sufficiently to compensate for future income reductions. Protecting low income households from saving too little would either require a higher mandatory contribution rate or lower interest rates on the hypothetical account for the benefit offset.

5 Discussion and Conclusions

In this paper, we have analyzed life-cycle saving, wealth accumulation and portfolio allocation decisions in a model with a taxable account and a funded, tax-deferred individual account in the presence of uninsurable labor income risk and borrowing constraints. 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. In addition, we have analyzed the impact of a perceived risk of a financial market downturn on optimal retirement savings in individual accounts.

Our results are limited by the experimental nature of our model exercises, however, we have gained some useful insights into the incentives that TDAs pose to participating households. Our results confirm the hypothesis that forcing agents to save a minimum fraction of their income crowds out retirement savings they would voluntarily undertake at later stages in life, generating welfare losses of 2 to 3 % measured in certainty-equivalent consumption. Mandatory carve-out accounts, on the contrary, have positive welfare effects for the middle and high income groups because of the benefits of converting social security contributions into individually managed TDAs with optimally chosen risky portfolio shares. For the low income group, however, mandatory carve-out accounts generate welfare losses as low income earners benefit less from the tax deferral and do not save sufficiently to compensate for future income reductions.

Our quantitative analysis has shown that the perceived risk of a financial market downturn affects the optimal portfolio choices substantially. While in normal times default portfolio rules have limited welfare effects, they imply higher utility costs in the presence of rare stock market disasters as they crowd out direct stock market participation. This finding is important given that many households may not be able to make informed investment decisions. Default investment rules can be considered as a device to limit the potential welfare costs generated by major investment mistakes for the financially less literate.

In our model, households that live in a world where financial crises can occur are limited in their optimizing behavior as they can only reshuffle their risky portfolio share to a safer investment option and adjust the level of their savings, both liquid and illiquid. In reality, households have more options to ensure themselves against the devastating effects of a financial disaster: they can decide to work longer years and increase their retirement benefits. Goda, Shoven, and Slavov (2011) and McFall (2011) provide recent evidence that TDA participants are responding to the sharp downturn of stock prices during the Great Recession by prolonging their working years. We leave the important question of savings in individual accounts and labor supply decisions in times of a stock market crash to future research.

Our paper has focused on the effects of individual accounts on households' savings and portfolio allocation decisions only. The introduction of different types of tax-deferred accounts, however, has general equilibrium effects on the entire economy as tax revenues are influenced. In addition, introducing carve-out accounts decreases the value of social security contributions and has potentially severe fiscal consequences during the transition period from an unfunded system to a system which is partially funded. Therefore, it is of particular interest for future research to analyze the general equilibrium effects of different types of individual accounts along the transition paths.

Appendix

A Numerical Algorithm

Our numerical algorithm follows Gomes et al. (2009). To reduce the number of state variables we normalize all variables by the permanent income component, P_t, and denote them by lower case letters. This reduces the number of state variables to w_t^τ, w_t^r, I_t, U_t and t.

The household decides to pay the fixed cost at age t and compares the two value functions:

$$v_t(w_t^t, w_t^r, U_t, I_t) = \max_{0,1}\{v_t(w_t^t, w_t^r, U_t, I_t = 0), v_t(w_t^t, w_t^r, U_t, I_t = 1)\}$$

The value function solves

$$v_t(w_t^t, w_t^r, U_t, I_t) = \Big\{\max_{c_t, k_t, \alpha_t^t, \alpha_t^r} \frac{c_t^{1-\rho}}{1-\rho} + \beta E_t\Big(\frac{P_{t+1}}{P_t}\Big)^{1-\rho} p_t v_t(w_t^t, w_t^r, U_t, I_t)\Big\}$$

subject to the normalized constraints (1), (2), (3), (4), depending on age and type of the individual account.

To solve the model, we start from the last period and proceed backwards. At any point in the state space we find the optimal choices by using grid search. We apply tensor product splines to interpolate for points that do not lie on the grid. Numerical integrations are performed using Gaussian quadrature. To take account of the higher curvature of the value function we follow Gomes et al. (2009) and use a grid with more points allocated to lower levels of wealth. To decide whether to pay the fixed stock market entry costs at time t the household compares the two value functions associated with direct stock market participation $I_t = 1$ and no direct access to stock markets $I_t = 0$. We take the maximum of the two value functions and derive the policy functions for the current period. Using these policy functions, we update this period's value function and proceed with solving the previous period's maximization problem. We iterate until $t = 1$.

B Utility Cost Calculation

To evaluate the welfare implications of different types of individual accounts, we calculate the utility costs of mandatory add-on and carve-out accounts relative to the benchmark scenario which we assume to be the voluntary add-on account with endogenous α^r. For each scenario, we calculate the constant consumption stream that makes the household as well-off in terms of expected utility. Utility costs are calculated in terms of percentage deviations in certainty-equivalent consumption relative to the benchmark scenario.

Following Cocco et al. (2005), we compute expected lifetime utility for each model scenario as follows. We start from the expected discounted life-time utility at the beginning of working life:

$$V_1 = E_1 \sum_{t=1}^{T} \beta^{t-1} \left(\prod_{j=0}^{t-1} p_j \right) \frac{C_t^{1-\rho}}{1-\rho}.$$

From this expression we calculate the equivalent constant consumption stream $\overline{C}$ that makes the agent indifferent between this constant consumption and the consumption stream they would obtain optimally:

$$V_1 = E_1 \sum_{t=1}^{T} \beta^{t-1} \left(\prod_{j=0}^{t-1} p_j \right) \frac{\bar{C}^{1-\rho}}{1-\rho}.$$

It follows that

$$\bar{C} = \left[\frac{(1-\rho)V}{\sum_{t=1}^{T} \beta^{t-1} (\prod_{j=0}^{t-1} p_j)} \right]^{\frac{1}{1-\rho}}$$

As an example, consider the welfare effects of mandatory add-on accounts. The utility cost in percentage-deviation in certainty-equivalent consumption is given by:

$$\text{Loss}^{\text{mandatory}} = \frac{\bar{C}^{\text{voluntary}} - \bar{C}^{\text{mandatory}}}{\bar{C}^{\text{mandatory}}}.$$

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Table 1: Individual Retirement Accounts Around the World

Type of Plan	Country	Name of Plan	Contribution Rate in %
Mandatory Add-on, funded	Sweden	Premium Pension	2.5
	Denmark	ATP	1.5
	Switzerland	BVG/LPP (Employer-provided)	7.0-8.0
	Australia	Superannuation Guarantee charge (Employer-provided)	9.0
Mandatory Add-on, unfunded	Sweden	Notional Account	16.5
	Italy	Notional Account	33.0
	France	ARRCO / AGIRC	14.0
Mandatory Carve-out, funded	Chile	Administradoras de Fondos de Pensiones	10.0
Voluntary Add-on, funded	United States	Individual Retirement Account, 401(k)	4000$ 18 max
	Canada	Registered Pension Plan	18.0 max
	United Kingdom	Personal Pensions	17.5 max
	Germany	Riester Pension	4.0
Voluntary Carve-out, funded	United Kingdom	Approved Personal Pension	4.6
	Colombia		

Source: Turner (2006), page 12.

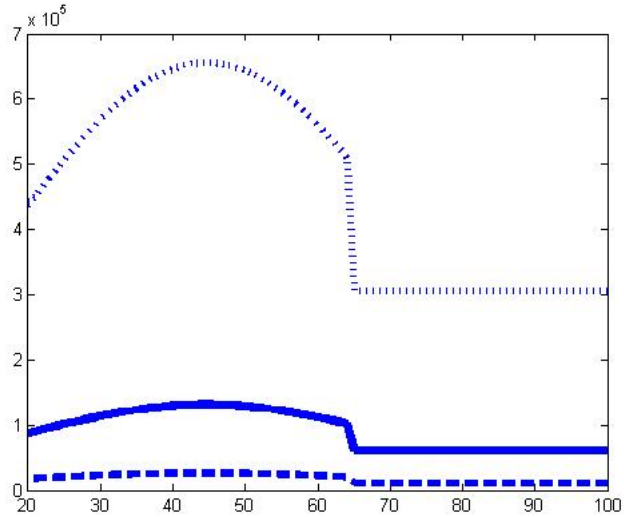
Table 2: Model Parameters for the Benchmark

Preferences	ρ	Risk aversion	4
	β	Discount rate	0.96
Labor income process	σ_U	Transitory shock	0.10
	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
Mandatory Add-on	$k^{\min}$	Minimum fixed contribution rate	0.03
Mandatory Carve-out	k^c	Mandatory carve-out rate	0.03
Stock market disaster	p	Annual disaster probability	0.0403
	ϕ	Stock market drop	0.278

Table 3: Tax Treatment of Different Income Groups

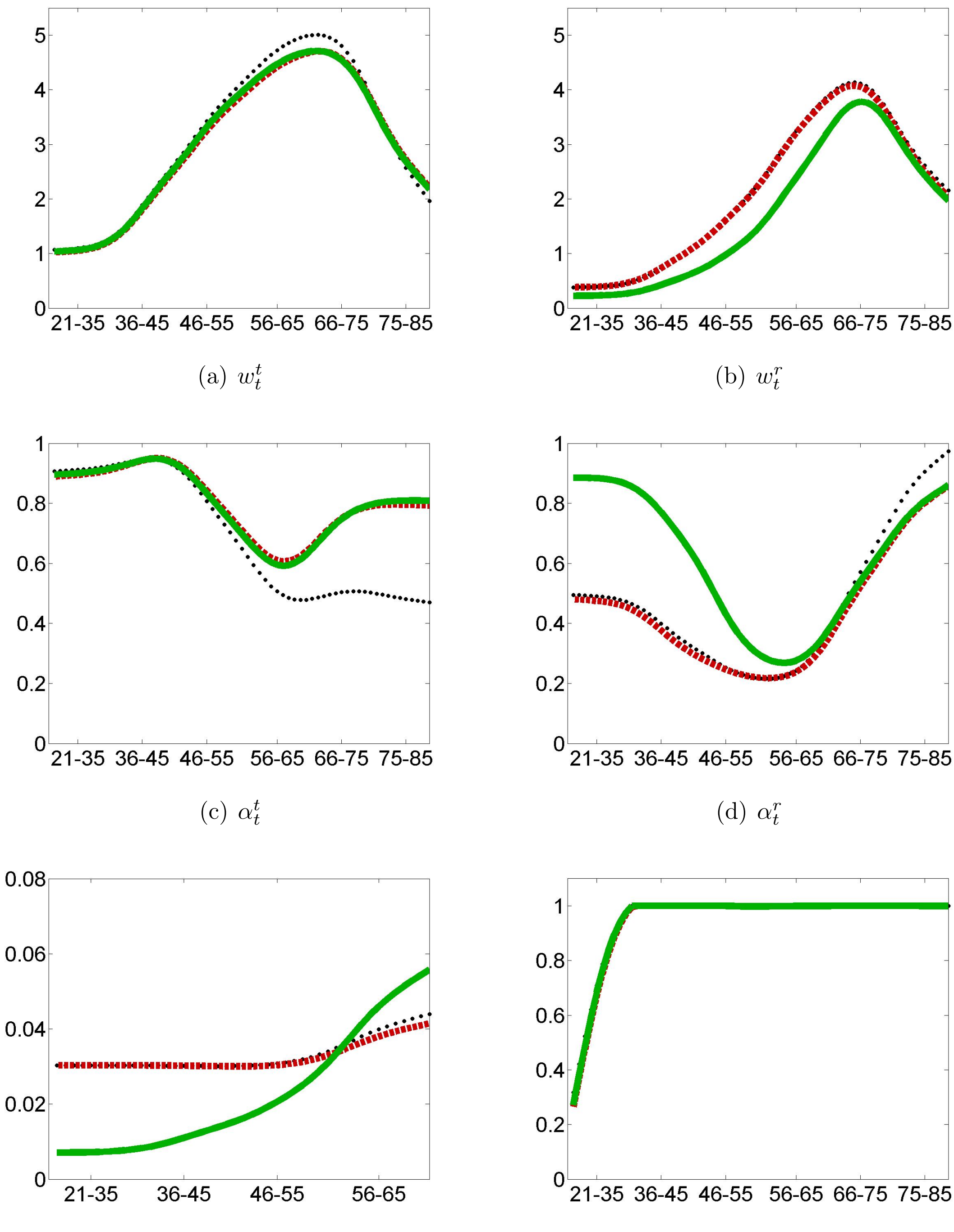
High income group	τ_d	Labor income tax	35%
	τ_b	Tax on bond returns	25%
	τ_g	Tax on stock returns	22.5%
	τ_s	Social security tax	6.5%
Middle income group (Benchmark)	τ_d	Labor income tax	25%
	τ_b	Tax on bond returns	25%
	τ_g	Tax on stock returns	22.5%
	τ_s	Social security tax	6.5%
Low income group	τ_d	Labor income tax	10%
	τ_b	Tax on bond returns	25%
	τ_g	Tax on stock returns	22.5%
	τ_s	Social security tax	6.5%

Figure 1: Gross Labor Income Profiles



Notes: The upper dashed line refers to gross, non-capital labor income for the high income group (college graduates) whereas the lower dashed line is the income profile of the low income group (less than high school). The solid line represents the middle income group and is the basis for the benchmark calibration. Profiles and parameters are taken from Fehr et al. (2005).

Figure 2: Life-Cycle Profiles



(a) w_t^t

(b) w_t^r

(c) α_t^t

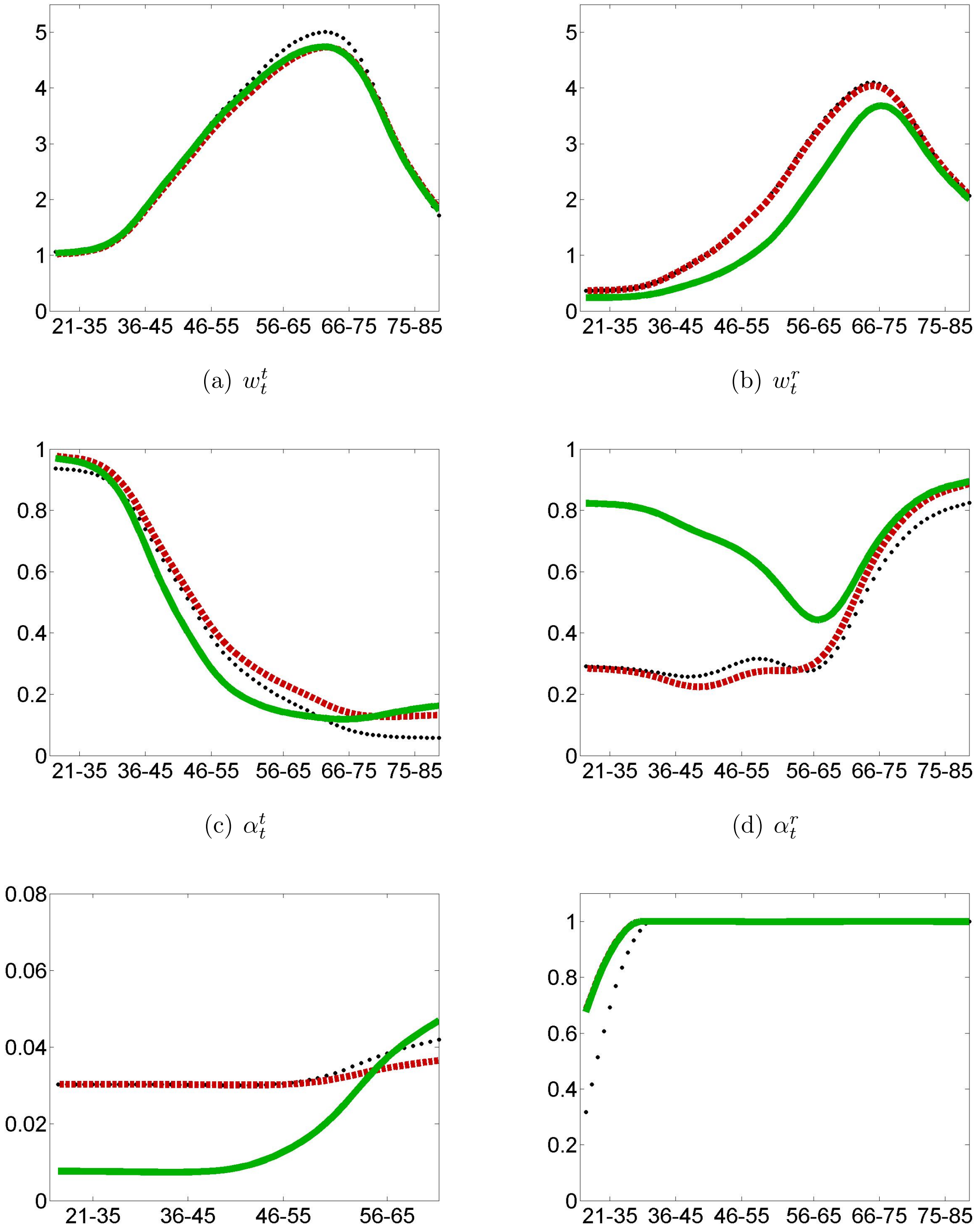
(d) α_t^r

(e) k_t

(f) Stock market participation rate

Notes: We simulate the life-cycle patterns for 10,000 households of the middle income group. The solid line refers to life-cycle patterns associated with voluntary add-on accounts, while the dashed and dotted lines correspond to life-cycle patterns associated with mandatory add-on and mandatory carve-out accounts, respectively. Panels (a) to (f) display the median wealth-to-earnings ratio in the TA w_t^t, the median wealth-to-earnings ratio in the TDA w_t^r, the mean conditional risky share in the TA α_t^t, the mean conditional risky share in the TDA α_t^r, the mean contribution rate to the TDA k_t and the stock market participation rate.

Figure 3: Life-Cycle Profiles with Disaster Expectations



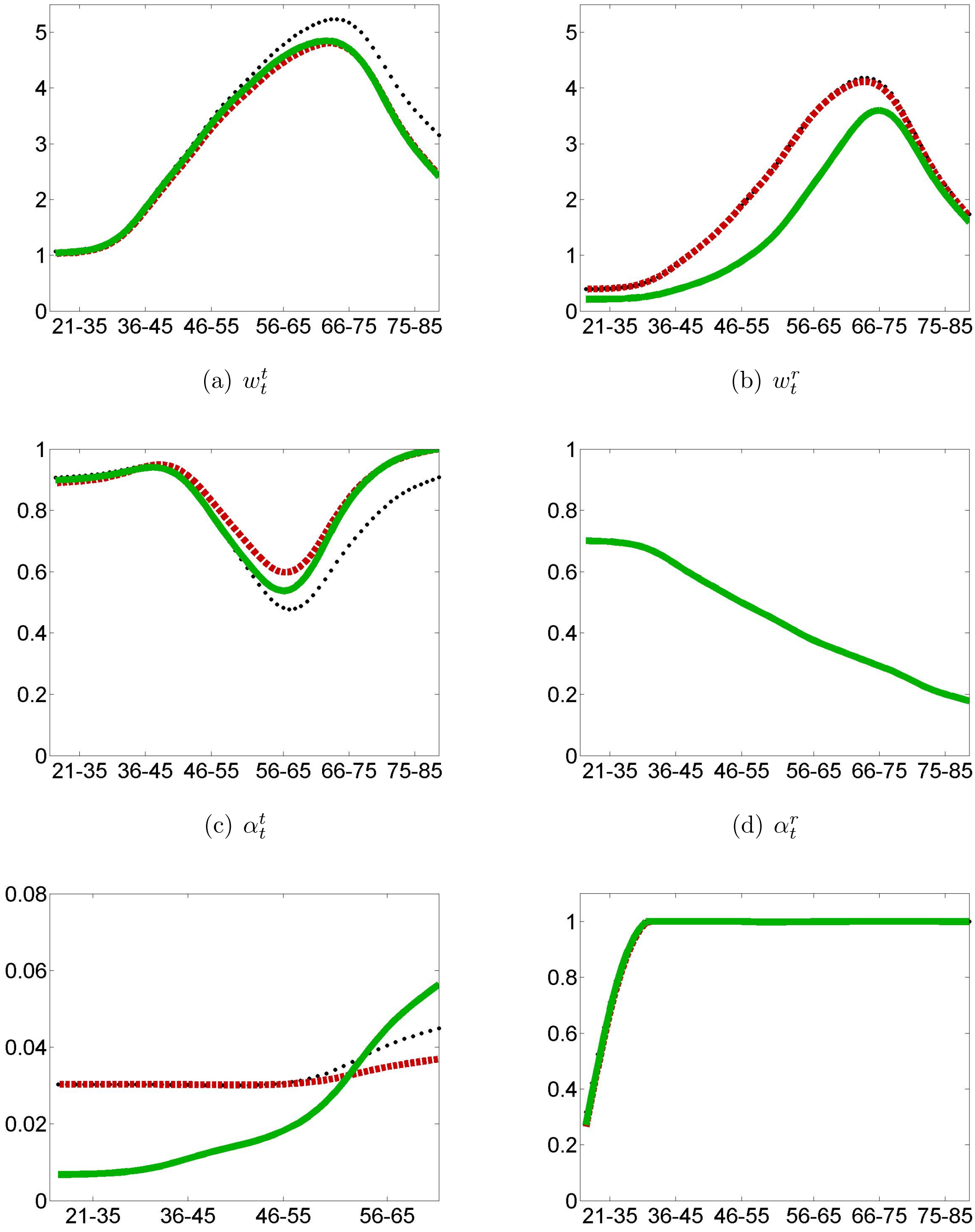
(a) w_t^t (b) w_t^r

(c) α_t^t (d) α_t^r

(e) k_t (f) Stock market participation rate

Notes: This figure assumes disaster expectations as specified in table 2. We simulate the life-cycle patterns for 10,000 households of the middle income group. The solid line refers to life-cycle patterns associated with voluntary add-on accounts, while the dashed and dotted lines correspond to life-cycle patterns associated with mandatory add-on and mandatory carve-out accounts, respectively. Panels (a) to (f) display the median wealth-to-earnings ratio in the TA w_t^t, the median wealth-to-earnings ratio in the TDA w_t^r, the mean conditional risky share in the TA α_t^t, the mean conditional risky share in the TDA α_t^r, the mean contribution rate to the TDA k_t and the stock market participation rate.

Figure 4: Life-Cycle Profiles with Default Investment Rule



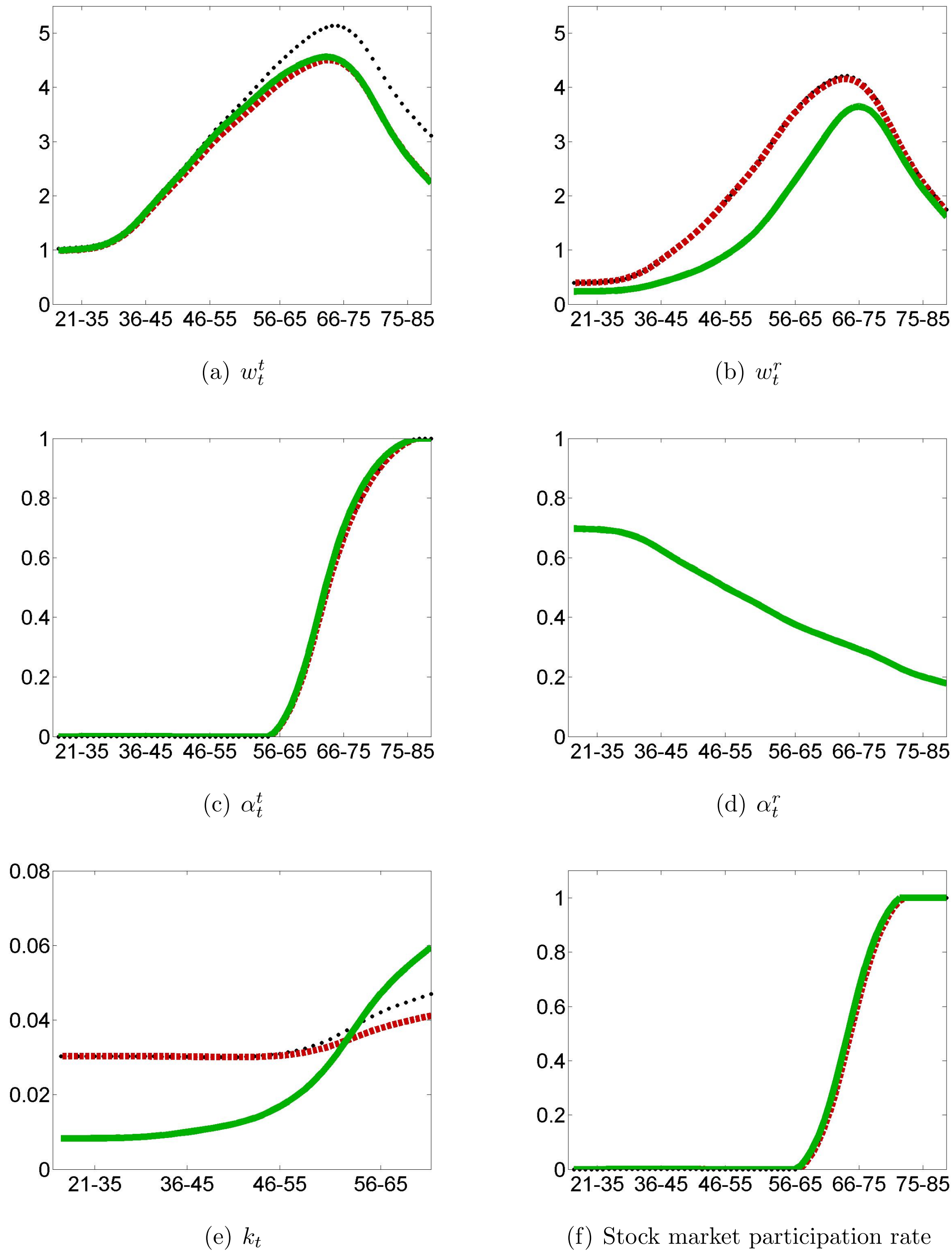
(a) w_t^t (b) w_t^r

(c) α_t^t (d) α_t^r

(e) k_t (f) Stock market participation rate

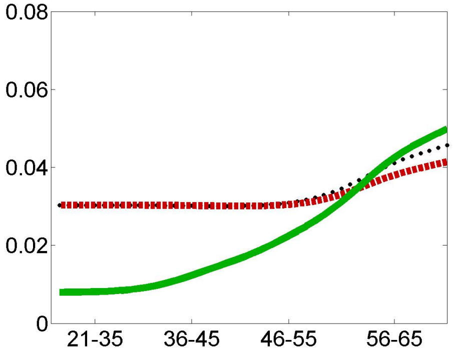
Notes: This figure assumes a default investment rule and exogenously fixes the portfolio choice $\alpha^r = (100 - \text{age})/100$. We simulate the life-cycle patterns for 10,000 households of the middle income group. The solid line refers to life-cycle patterns associated with voluntary add-on accounts, while the dashed and dotted lines correspond to life-cycle patterns associated with mandatory add-on and mandatory carve-out accounts, respectively. Panels (a) to (f) display the median wealth-to-earnings ratio in the TA w_t^t, the median wealth-to-earnings ratio in the TDA w_t^r, the mean conditional risky share in the TA α_t^t, the mean conditional risky share in the TDA α_t^r, the mean contribution rate to the TDA k_t and the stock market participation rate.

Figure 5: Life-Cycle Profiles with Disaster Expectations and Default Investment Rule

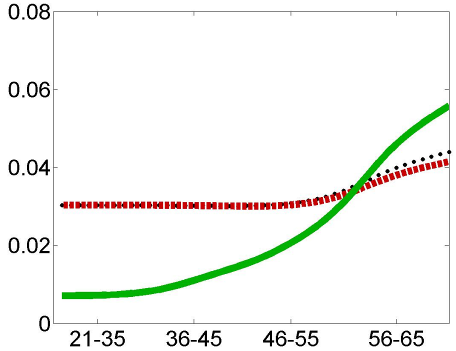


Notes: This figure assumes disaster expectations as specified in table 2 and exogenously fixes the portfolio choice $\alpha^r = (100 - \text{age})/100$. We simulate the life-cycle patterns for 10,000 households of the middle income group. The solid line refers to life-cycle patterns associated with voluntary add-on accounts, while the dashed and dotted lines correspond to life-cycle patterns associated with mandatory add-on and mandatory carve-out accounts, respectively. Panels (a) to (f) display the median wealth-to-earnings ratio in the TA w_t^t, the median wealth-to-earnings ratio in the TDA w_t^r, the mean conditional risky share in the TA α_t^t, the mean conditional risky share in the TDA α_t^r, the mean contribution rate to the TDA k_t and the stock market participation rate.

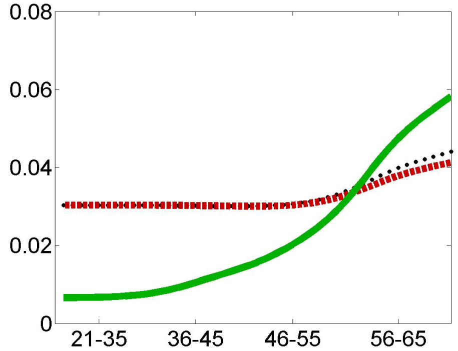
Figure 6: Life-Cycle Profiles for Different Income Groups



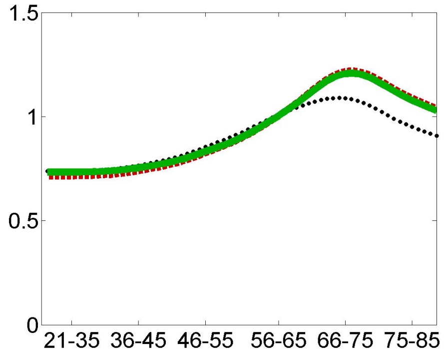
(a) k_t: Low income group



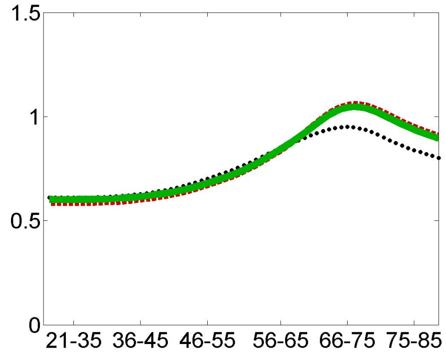
(b) k_t: Middle income group



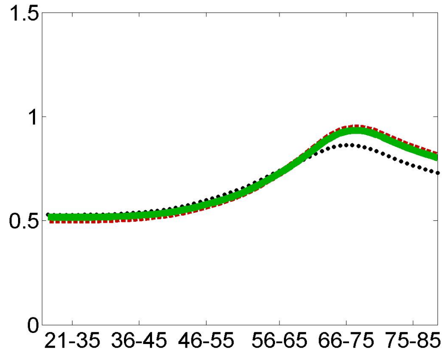
(c) k_t: High income group



(d) c_t: Low income group



(e) c_t: Middle income group



(f) c_t: High income group

Notes: We simulate the life-cycle patterns for 10,000 households of the low, the middle and the high income groups. The solid line refers to life-cycle patterns associated with voluntary add-on accounts, while the dashed and dotted lines correspond to life-cycle patterns associated with mandatory add-on and mandatory carve-out accounts, respectively. The panels plot the mean contribution rates to the TDA k_t and mean consumption c_t normalized by permanent income.

Table 4: Utility Costs

	Endogenous α_r			Exogenous α_r	
	Mandatory Add-on	Mandatory Carve-out	Voluntary Add-on	Mandatory Add-on	Mandatory Carve-out
Middle income group	2.31	-0.87	0.20	2.39	-0.68
High income group	2.06	-2.04	0.20	2.13	-1.98
Low income group	2.78	0.50	0.15	2.83	0.52

Notes: This table evaluates the welfare consequences of different types of individual accounts across income groups. The middle income group is the benchmark calibration. Welfare losses and gains of mandatory add-on and carve-out accounts are given relative to the voluntary add-on account with endogenous α^r. For each scenario, we calculate the constant consumption stream that makes the household as well-off in terms of expected utility. Utility costs are calculated as percentage deviations in certainty-equivalent consumption relative to the voluntary add-on account with endogenous α^r.

Table 5: Utility Costs with Disaster Expectations

	Endogenous α_r			Exogenous α_r	
	Mandatory Add-on	Mandatory Carve-out	Voluntary Add-on	Mandatory Add-on	Mandatory Carve-out
Middle income group	2.17	-1.02	1.48	3.62	0.52
High income group	1.76	-2.34	1.36	3.25	-0.88
Low income group	2.48	0.16	1.11	3.66	1.27

Notes: This table considers disaster expectations and evaluates the welfare consequences of different types of individual accounts across income groups. The middle income group is the benchmark calibration. Welfare losses and gains of mandatory add-on and carve-out accounts are given relative to the voluntary add-on account with endogenous α^r. For each scenario, we calculate the constant consumption stream that makes the household as well-off in terms of expected utility. Utility costs are calculated as percentage deviations in certainty-equivalent consumption relative to the voluntary add-on account with endogenous α^r.

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