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PENSION FUNDING AND INDIVIDUAL ACCOUNTS IN ECONOMIES WITH LIFE-CYCLERS AND MYOPES *

Hans Fehr, Fabian Kindermann

ABSTRACT: The present paper Studies the growth and efficiency consequences of pension funding with individual retirement accounts in a general equilibrium overlapping generations model with idiosyncratic lifespan and labor income uncertainty. We distinguish between economies with rational and hyperbolic consumers and compare the consequences of voluntary and mandatory retirement plans. Three major findings are derived in our study: First, we quantify the commitment effect of social security for myopic individuals by roughly 1 percent of aggregate resources. It is possible to recapture this commitment technology in IRAs, if those are annuitized. Second, despite the fact that our consumers have an operative bequest motive, the welfare gain from the (implicit) longevity insurance of the pension system is significant and amounts to roughly 0.5 percent of aggregate resources. However, mandatory annuitization reduces unintended bequests so that future generations are significantly hurt. Finally, our results highlight the importance of liquidity effects for social security analysis. These efficiency gains are only attainable if accounts are voluntary and not mandatory.

JEL Codes: H55, J26

Keywords: individual retirement accounts, annuities, stochastic general equilibrium, hyperbolic consumers

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1 Introduction

Governments around the world are currently introducing or are considering the introduction of individual retirement accounts (IRAs) as a supplement to or a (at least partial) substitute for the existing public pension system. Due to population ageing, the current benefit-wage ratios of pay-as-you-go financed retirement systems are hardly sustainable. It is hoped that individual accounts reduce labor and capital market distortions and accumulate additional private savings to secure the standard of living of future workers and retirees without harming current generations, see the discussion in Feldstein and Liebman (2002).

However, the economic rational for the shift towards funded pensions is not undisputed. Critics point out that such a reform hardly improves economic efficiency. Welfare gains of future cohorts are mainly generated by welfare losses of transitional generations. In addition, they claim that it is misleading to analyze social security in the framework of fully rational decision making and a set of complete markets. Among other reasons, social security was introduced in the first place to prevent myopic individuals from inadequate savings for retirement and to substitute the missing market for annuities, see Lindbeck and Persson (2003, p. 77) or Diamond (2004, p. 4). Therefore, recent attempts by Diamond and Köszegi (2003), Cremer, De Donder, Maldonado and Pestieau (2007) or Hurst and Willen (2007) analyze social security design issues in models with short-sighted and fully rational individuals.

The present paper adds to this literature by comparing the economic consequences of social security funding with individual accounts in a general equilibrium life-cycle model populated by either rational or hyperbolic individuals. Our model features idiosyncratic income and life-span uncertainty, missing private annuity markets and credit constrained consumers. Our initial equilibrium is calibrated to the German economy, since the German pension system offers a special case for social security funding issues. Due to the strong tax-benefit linkage of the current paygo system, intra-cohort redistribution is fairly low. In addition, current paygo benefits are tax deferred in Germany such that the tax structure is not altered by the introduction of IRAs. As a consequence, our discussion could (mostly) abstract from labor supply distortions and insurance effects against income shocks. Instead, we isolate the commitment effect, the insurance provision against longevity and the liquidity effect of both social security and individual accounts.

Three major findings from the paper are important for the current political debate. First, in our most preferred calibration the commitment effect of social security roughly amounts to 1 percent of aggregate resources. As a consequence, the elimination (or privatization) of social security without individual accounts would reduce economic efficiency in the myopic economy. In the case of rational individuals, the liquidity gain and the improved insurance provision of the tax system dominate the (negative) effect from the eliminated annuity provision so that economic efficiency increases slightly by 0.2 percent of aggregate resources. Second, our simulations demonstrate that individual accounts which are annuitized after retirement are able to replace the commitment technology of social security for hyperbolic individuals. Therefore, funding social security with individual accounts increases economic efficiency significantly by roughly 0.7 percent of aggregate resources in both cases considered. However, annuitization reduces the welfare gain of future generations substantially, since it dampens accidental bequests. Third, the reported efficiency gains from the introduction of IRAs are mainly due to the improved liquidity of younger households. Consequently, mandatory accounts would (almost) completely eliminate them. This reasoning also applies to hyperbolic consumers who additionally use the accounts to commit themselves.

The next section discusses the related literature on IRAs and social security funding. Section 3 describes the structure of our simulation model and the computational algorithm. Section 4 explains the calibration of the initial equilibrium while section 5 presents our simulation results. The last section offers some concluding remarks.

2 Related literature

Various studies have already quantified the growth, distributional and efficiency implications of government sponsored retirement accounts. Engen, Gale and Scholz (1994) examine the effectiveness of individual retirement accounts in the U.S. Applying a partial equilibrium life-cycle model with income and life span uncertainty, they compute the optimal individual saving behavior for alternative contribution limits and withdrawal rates. Their simulations indicate that individuals will mainly substitute from liquid savings in the short run and increase their aggregate savings only slightly in the long run. Laibson, Repetto and Tobacman (1998) extend this approach by considering consumers with hyperbolic discount functions. Their analysis confirms that tax-favored retirement schemes have a bigger impact on hyperbolic consumers, since the latter value commitment. Love (2006) introduces job loss and unemployment insurance (UI) into this framework in order to measure the extent of precautionary savings in U.S. accounts. Since withdrawals before retirement are possible with a modest penalty, he finds that 401(k) plans may also serve as a precautionary savings vehicle. There is a positive effect on aggregate savings which decreases with the generosity of the UI system. Love (2007) extends the analysis of Engen et al. (1994) by quantifying the impact of employer matching, vesting periods and withdrawal penalties on individual saving behavior in 401(k) plans. Finally, Pries (2007) focusses on the welfare and distributional consequences of switching from social security to a mandatory system of so-called personal retirement accounts (PRAs). The study highlights the importance of liquidity effects. In order to improve life-cycle consumption smoothing and the accumulation of precautionary savings, it argues in favor of a PRA-system where contribution rates increase with age.

Whereas the partial equilibrium approach of Pries (2007) does not consider how to finance the currently existing social security liabilities, the present study includes such issues by applying a general equilibrium model with overlapping generations which was pioneered by Auerbach and Kotlikoff (1987). This approach has been applied in numerous quantitative studies on social security funding. Starting with İmrohoroğlu, İmrohoroğlu and Joines (1995), the model has been extended to include individual income and mortality risk, in order to quantify the insurance properties of the public sector.[1]

İmrohoroğlu et al. (1998) evaluate the long-run effects of IRAs on the U.S. capital stock for various contribution limits and tax savings instruments. They conclude that about 9 percent of IRA contributions during the 80ies constituted additional savings which raised the capital stock by about 6 percent. Fehr, Habermann and Kindermann (2008a) as well as Fehr and Habermann (2008a) extend this analysis by including the transition to the new long-run equilibrium and computing the welfare and efficiency consequences. Whereas Fehr et al. (2008a) concentrate on the effects of contribution ceilings and alternative tax arrangements, Fehr and Habermann (2008a) analyze some specific features of the recent IRA introduction in Germany such as mandatory annuitization. Both studies confirm the steady-state growth effects of IRAs from İmrohoroğlu et al. (1998) and indicate a significant increase in future generations' welfare. However, since aggregate efficiency is hardly affected, future welfare gains come at the cost of transitional welfare losses. If accounts are annuitized, future generations might even lose due to the reduction of accidental bequest.

Fuster, İmrohoroğlu and İmrohoroğlu (2008) present a first approach, where individual retirement accounts are introduced as a substitute for (and not as a supplement to) the existing social security system. Their model features two-sided altruism where individual life expectancy and income are positively correlated. Starting from a benchmark which reflects the existing U.S. pay-as-you-go social security system, they either eliminate the existing system or substitute half of the contributions by mandatory savings in private accounts which are either annuitized or not after retirement. While all reforms induce an increase in the steady-state capital stock between 6 and 9 percent, the mandatory saving programs outperforms the full privatization policy in terms of long-run capital and consumption growth. As in Fehr and Habermann (2008a) annuitization decreases accidental bequest. However, long-run welfare does not necessarily decrease due to annuitization. Households without parents

[1] Older numerical simulation studies are surveyed in Lindbeck and Persson (2003). For the more recent literature see Krueger (2006).

alive are hurt by annuitization and even prefer a full privatization policy, since mandatory savings increase their liquidity constraints. On the other hand, most households with both parents and children benefit from a mandatory saving programm with annuitized pay-outs, since parents like to hold annuities during retirement. Consequently, Fuster et al. (2008) demonstrate that annuitization could affect different household types within a cohort quite differently. However, since the study only considers long-run equilibria, the reported welfare effects could be due to intergenerational redistribution or due to increased efficiency. The present study considers the transition to the new long-run equilibrium in order to analyze this issue in more detail.

Our study is also related to recent general equilibrium studies which analyze the welfare effects of social security funding in models where individuals exhibit problems of self-control. While İmrohoroğlu et al. (2003) consider social security in a model where consumers exhibit time-inconsistent preferences, Kumru and Thanopoulos (2008) model preferences where agents are tempted to consume in every period. Although individuals with problems of self-control value social security either as a commitment device or a device which reduces the cost of temptation, both studies find that the introduction of social security still decreases long-run welfare for reasonable short-run discount rates. However, both studies neglect transitional cost (or benefits) and therefore fail to isolate the exact commitment effect which social security provides to short-sighted consumers. The latter is done in Fehr et al. (2008b) where we compare the elimination of social security in an economy populated by either rational or hyperbolic consumers. The present study directly extends our previous one by considering the introduction of an IRA system as a substitute for social security. Here we extend the existing literature by documenting the important role of IRAs as a commitment device and by analyzing the implications of mandatory accounts.

3 The model economy

3.1 Demographics and intracohort heterogeneity

We consider an economy populated by overlapping generations of individuals which may live up to a maximum possible lifespan of J periods. At the beginning of each period, a new generation is born where we assume a population growth rate of n. Since individuals face lifespan uncertainty, $\psi_j < 1$ denotes the time-invariant conditional survival probability from age $j-1$ to age j with $\psi_{J+1} = 0$.

Our model is solved recursively. Consequently, an age-j agent faces the state vector

$$z_j = (\mathrm{a}_j, \mathrm{a}_j^R, ep_j, e_j) \tag{1}$$

where $\mathrm{a}_j \in A = [\underline{\mathrm{a}}, \bar{\mathrm{a}}]$ denotes (liquid) assets held at the beginning of age j, $\mathrm{a}_j^R \in R = [\underline{\mathrm{a}}^R, \bar{\mathrm{a}}^R]$ are assets in individual retirement accounts held at the beginning of age j, $ep_j \in P = [\underline{ep}, \overline{ep}]$ defines the agent's accumulated earning points for public pension claims and $e_j \in E_j = [\underline{e}_j, \overline{e}_j]$ is the individual productivity at age j.

The productivity state is assumed to follow a first-order Markov process described in more detail below. Consequently, each age-j cohort is fragmented into subgroups $\xi(z_j)$, according to the initial distribution at age $j = 1$, mortality, population growth, the Markov process and optimal household decisions. Let $X(z_j)$ be the corresponding cumulated measure to $\xi(z_j)$. Hence,

$$\int_{E_1} \mathrm{d}X(z_1) = 1 \quad \text{with} \quad z_1 = (0, 0, 0, e_1) \tag{2}$$

must hold, since we have normalized the cohort size of newborns to be unity. Let $\mathbf{1}_{h=x}$ be an indicator function that returns 1 if $h = x$ and 0 if $h \neq x$. Let $Z_t = (\xi_t(z_j), \Psi_t)$ denote the state of the economy at the beginning of period t, where Ψ_t defines the known policy schedule of the government at t. Then, the law of motion of the measure of households is, for $j \in (1, \dots, J)$,

$$\xi_{t+1}(z_{j+1}) = \frac{\psi_{j+1}}{1+n} \int_{A\times R\times P\times E_j} \mathbf{1}_{a_{j+1}=a_{j+1}(z_j,Z_t)} \times \mathbf{1}_{a_{j+1}^R=a_{j+1}^R(z_j,Z_t)} \times \mathbf{1}_{ep_{j+1}=ep_{j+1}(z_j,Z_t)} \pi_j(e_{j+1}|e_j)\mathrm{d}X_t(z_j), \tag{3}$$

where $\pi_j(e_{j+1}|e_j)$ denotes the probability at age j to experience productivity e_{j+1} in the next period if the current productivity is e_j.

In the following, we will omit the time index t and the state indices z_j and Z_t for every variable whenever possible. Agents are then only distinguished according to their age j.

3.2 The individual decision problem

Our model assumes a preference structure that is represented by a time-separable, nested CES utility function. We distinguish between rational and hyperbolic consumers. The former exhibit time-consistent preferences and consequently do not regret their previous decisions in the future. Following the seminal work of Strotz (1956), we model the decision problem of a hyperbolic consumer as an intrapersonal game between a sequence of "selves" with conflicting preferences. Taking the strategies of his future selves as given, the current self picks a strategy that is optimal from his own perspective.

The consumer at age j and state z_j in period t first has to forecast his future actions. He believes that his future self (who is at age $j+1$) will choose consumption, leisure and IRA savings in order to maximize the objective function

$$\max_{\hat{c}_{j+1}, \hat{\ell}_{j+1}, \hat{s}_{j+1}} \left\{ u(\hat{c}_{j+1}, \hat{\ell}_{j+1}) + \hat{\beta}\delta \left[\psi_{j+2} E\hat{V}(z_{j+2}, Z_{t+2}) + (1-\psi_{j+2})\mathcal{B}(\hat{q}_{j+2}) \right] \right\}. \tag{4}$$

Since life-span is uncertain, the (believed) expected value function $E\hat{V}(\cdot)$ of the future is weighted with the survival probability ψ_{j+2} while utility from (believed) bequests $\hat{q}_{j+2}$ is weighted with the probability to die.[2] The expectation operator E in (4) indicates that future utilities are computed over the distribution of e_{j+2}. Hence,

$$E\hat{V}(z_{j+2}, Z_{t+2}) = \int_{E_{j+2}} \hat{V}(z_{j+2}, Z_{t+2})^{1-\frac{1}{\gamma}} \Pi_{j+1}(\mathrm{d}e_{j+2}|e_{j+1}), \tag{5}$$

where γ defines the intertemporal elasticity of substitution and $\Pi_{j+1}(e_{j+2}|e_{j+1})$ denotes the cumulative density function of the respective probability $\pi_{j+1}(e_{j+2}|e_{j+1})$ to experience productivity e_{j+2} in the next period if the current productivity is e_{j+1}. Utility from leaving bequest is simply computed from

$$\mathcal{B}(\hat{q}_{j+2}) = \mu\, \hat{q}_{j+2}^{1-\frac{1}{\gamma}} \qquad \mu \geq 0, \tag{6}$$

where μ defines the strength of the bequest motive. In (4) expected utility is discounted with δ and the hyperbolic parameter $\hat{\beta}$ which allows to distinguish between so called "naive" and "sophisticated" hyperbolic consumers, see O'Donoghue and Rabin (1999). The former think that their future selves will behave in a time-consistent manner despite the fact that they have consistently violated this belief in the past, i.e. $\hat{\beta} = 1$. The latter correctly foresee that their future selves will also behave in a time-inconsistent way, i.e. $\hat{\beta} = \beta$ where β defines the discount rate of the current selves. Consequently, $\hat{c}_{j+1}$, $\hat{\ell}_{j+1}$ and $\hat{s}_{j+1}$ denote the believe of the current self about his future actions.

The value function $\hat{V}(\cdot)$ for future beliefs (with $\hat{c}_{j+1}, \hat{\ell}_{j+1}, \hat{s}_{j+1}$ and $\hat{q}_{j+2}$ from (4)) is computed for any age $j+1$ in period $t+1$ from

$$\hat{V}(z_{j+1}, Z_{t+1}) = u(\hat{c}_{j+1}, \hat{\ell}_{j+1}) + \delta \left[\psi_{j+2} E\hat{V}(z_{j+2}, Z_{t+2}) + (1-\psi_{j+2})\mathcal{B}(\hat{q}_{j+2}) \right]. \tag{7}$$

The current self at age $j = 1, \ldots, J$ in period t maximizes the objective function

$$\max_{c_j, \ell_j, s_j} \left\{ u(c_j, \ell_j) + \beta\delta \left[\psi_{j+1} E\hat{V}(z_{j+1}, Z_{t+1}) + (1-\psi_{j+1})\mathcal{B}(\hat{q}_{j+1}) \right] \right\}, \tag{8}$$

[2]This type of bequest motive has been called *warm glow* (De Nardi, 2004). Fuster et al. (2008) model intergenerational links quite differently.

which already reflects the believes about his/ her future behavior. Note that the decision functions $c_j(z_j, Z_t)$, $\ell_j(z_j, Z_t)$ and $s_j(z_j, Z_t)$ now denote the actual behavior of the agent. They are also used to compute agent's welfare, i.e.

$$V(z_j, Z_t) = u(c_j, \ell_j) + \delta \left[\psi_{j+1} EV(z_{j+1}, Z_{t+1}) + (1 - \psi_{j+1}) \mathcal{B}(q_{j+1}) \right] . \tag{9}$$

The time-inconsistency in preferences is evident from the fact that the β and $\hat{\beta}$ terms appear in the decision problems (4) and (8) but not in the calculation of value functions (7) and (9). It should also be clear that for $\beta = \hat{\beta}$ the decision and value functions of the beliefs $\hat{c}_j, \hat{\ell}_j, \hat{s}_j$ and $\hat{V}$ and the respective functions of the actual behavior c_j, ℓ_j, s_j and V coincide. Consequently, sophisticated hyperbolic consumers (where $\beta = \hat{\beta} < 1$) behave differently compared to time-consistent consumers (i.e. where $\beta = \hat{\beta} = 1$) but the solution algorithm is quite similar.[3]

Finally, the period utility function is defined by

$$u(c_j, \ell_j) = \frac{1}{1 - \frac{1}{\gamma}} \left[(c_j)^{1-\frac{1}{\rho}} + \alpha(\ell_j)^{1-\frac{1}{\rho}} \right]^{\frac{1-\frac{1}{\gamma}}{1-\frac{1}{\rho}}} , \tag{10}$$

where ρ denotes the intratemporal elasticity of substitution between consumption and leisure at each age j while α is the age-independent leisure preference parameter.

Current selves maximize (8) subject to the budget constraint

$$\mathrm{a}_{j+1} = \mathrm{a}_j(1 + r) + w_j + p_j + b_j + v_j - s_j - \tau \min[w_j; 2\bar{w}] - T(y_j) - (1 + \tau_c)c_j \tag{11}$$

with $\mathrm{a}_1 = \mathrm{a}_{J+1} = 0$ and $\mathrm{a}_j \geq 0 \; \forall \; j$. In addition to interest income from savings $r\mathrm{a}_j$, households receive gross labor income $w_j = w(1 - \ell_j)e_j$ during their working period as well as public pensions p_j during retirement. As time endowment is normalized to one, w defines the wage rate for effective labor. At specific ages, households also receive accidental bequests b_j and in specific simulations they receive (or have to pay) lump-sum transfers v_j which are explained below. Households contribute to or withdraw from retirement accounts s_j and have to pay social security contributions and income taxes. We eliminate the liquidity of retirement accounts during employment completely[4] and do not allow for positive contributions after retirement, i.e.

$$s_j \geq 0 \quad \text{if} \quad j < j_R \qquad \text{and} \quad s_j \leq 0 \quad \text{if} \quad j \geq j_R. \tag{12}$$

[3]For naive hyperbolic consumers (i.e. where $\beta < 1$ and $\hat{\beta} = 1$) the decision functions of believes (4) and actual behavior (8) do not coincide so that the computational algorithm has to be specified differently. In the following we only report results with sophisticated hyperbolic consumers. The difference with naive hyperbolic consumers is only minor.

[4]Consequently, in contrast to Love (2006), accounts will not accumulate precautionary savings.

Contributions at a rate τ are paid to the public pension system up to a ceiling which amounts to the double of average income $\bar{w}$. Income taxes depend on taxable income y_j and the tax schedule $T(\cdot)$ which is explained below. Finally, the price of consumption goods c_j includes consumption taxes τ_c.

Retirement account assets accumulate according to

$$\mathrm{a}^R_{j+1} = \mathrm{a}^R_j(1+r_j) + \min[s_j, \hat{s}_j] \qquad \text{with} \quad r_j = \frac{1+r}{\max[\omega_j, \psi_j]} - 1, \tag{13}$$

where $\mathrm{a}^R_1 = 0$ and $\mathrm{a}^R_j \geq 0 \ \forall \ j$. Without annuitization at age j, we set $\omega_j = 1$ so that the survival probability ψ_j has no effect on the individual return, i.e. $r_j = r$. If retirement account assets are annuitized at age j, we set $\omega_j = 0$ so that $r_j > r$. Contributions cannot exceed the contribution limit $\hat{s}_j$ which is specified below. After retirement (i.e. $j \geq j_R$ and $s_j \leq 0$) we have to distinguish two cases: First, without mandatory annuitization, retired households can decide how much to withdraw. Second, with mandatory annuitization, we follow Fuster et al. (2008) and assume that retirees receive a fixed benefit, depending on their wealth at the beginning of retirement $\mathrm{a}^R_{j_R}$:

$$s_j = s_{j_R} = -\frac{(1+r_{j_R})\mathrm{a}^R_{j_R}}{\sum_{j=j_R}^{J} \Pi_{i=j_R+1}^{j}(1+r_i)^{-1}}. \tag{14}$$

Accumulated earning points of the pension system depend on the relative income position $w_j/\,\bar{w}$ of the worker at working age $j < j_R$. Since the contribution ceiling is fixed at the double of average income $\bar{w}$, maximum earning points collected per year are 2. Therefore, earning points accumulate according to

$$ep_{j+1} = ep_j + \nu \min[w_j/\,\bar{w}; 2], \tag{15}$$

where $ep_1 = 0$. The credit factor ν is set at 1 in the initial equilibrium and then reduced to zero by the reform.

Our model abstracts from private annuity markets. Consequently, private assets of all agents who died are aggregated and then distributed among all working age cohorts following an exogenous age- and productivity-dependent distribution scheme $\Gamma_j(e_j)$, i.e.

$$b_j(z_j, Z_{t+1}) = \frac{\Gamma_j(e_j)}{1+n} \sum_{i=1}^{J} (1-\psi_{i+1}) \int_{A\times R\times P\times E_i} q_{i+1}(z_i, Z_t) \mathrm{d}X_t(z_i) \quad \forall \quad j < j_R, \tag{16}$$

where $q_{i+1}(z_i, Z_t) = (1+r)[\mathrm{a}_{i+1}(z_i, Z_t) + \omega_{i+1}\mathrm{a}^R_{i+1}(z_i, Z_t)(1-\tau_b)]$. The age distribution of bequests is computed in the initial steady state, where we assume that heirs always receive assets of the generation which was 25 years older. Since bequest can only be received during employment, we adjust this rule at the beginning and the end of employment. Within a generation bequests are distributed proportional to the current productivity level e_j, which highlights their stochastic nature and also reflects empirical evidence.[5] Finally, inheritances from IRAs are due to a specific inheritance tax τ_b, since they were accumulated tax free.

3.3 The production side

Firms in this economy use capital and labor to produce a single good according to a Cobb-Douglas production technology $Y_t = \varrho K_t^{\varepsilon} L_t^{1-\varepsilon}$ where Y_t, K_t and L_t are aggregate output, capital and labor in period t, respectively, ε is capital's share in production, and ϱ defines a technology parameter. Capital depreciates at a constant rate δ_k and firms have to pay corporate taxes $T_{k,t} = \tau_k [Y_t - w_t L_t - \delta_k K_t]$, where a time-invariant corporate tax rate τ_k is applied to output net of labor costs and depreciation. Firms maximize profits renting capital and hiring labor from households so that net marginal products equal r_t the interest rate for capital and w_t the wage rate for effective labor.

3.4 The government sector

Our model distinguishes between the tax system and the pension system. In each period t, the government issues new debt $(1+n)B_{G,t+1} - B_{G,t}$ and collects taxes from households and firms in order to finance general government expenditure G which is fixed per capita as well as interest payments on its debt, i.e.

$$(1+n)B_{G,t+1} - B_{G,t} + T_{y,t} + T_{k,t} + T_{b,t} + \tau_{c,t}C_t = G + r_t B_{G,t}. \tag{17}$$

Revenues of income and bequest taxation are computed from

$$T_{y,t} = \sum_{j=1}^{J} \int_{A\times R\times P\times E_j} T(y_j(z_j, Z_t))\mathrm{d}X_t(z_j)$$

and

$$T_{b,t} = \tau_b \sum_{j=1}^{J} \int_{A\times R\times P\times E_j} \omega_{j+1}(1-\psi_{j+1})(1+r_t)\mathrm{a}_{j+1}^{R}(z_j, Z_t)\mathrm{d}X_t(z_j)$$

and C_t defines aggregate consumption (see (26)).

We assume that contributions to public pensions are exempted from tax while benefits are fully taxed. Consequently, taxable income y_j is computed from gross labor income net of

[5] De Nardi (2004) highlights the link between individual productivity and inheritance. Fehr et al. (2008a) also report the consequences of alternative bequest distributions.

pension contributions, a flexible work related allowance $d(w_j)$, capital income and – after retirement – public pensions. By means of θ, we can distinguish between fully taxed and tax deferred retirement accounts. In the former case (i.e. when $\theta = 1$) savings in retirement accounts are taxed as ordinary savings, whereas in the latter case (i.e. when $\theta = 0$) contributions to retirement accounts are tax deductible (up to the contribution limit) and withdrawals after retirement have to be fully taxed. Hence,

$$y_j = \max[w_j - \tau \min[w_j, 2\bar{w}] - d(w_j); 0] + r(\mathrm{a}_j + \theta \mathrm{a}_j^R) + p_j - (1-\theta)\min[s_j, \hat{s}_j]. \tag{18}$$

Given taxable income, we apply the progressive tax code of 2005 (including a solidarity surcharge τ_z of 5.5 percent) in Germany, i.e. $T(y_j) = (1+\tau_z)T05(y_j)$. After the policy reform, the intertemporal budget of the government is balanced by a one time adjustment of the consumption tax rate.

In each period, the pension system pays old-age benefits and collects payroll contributions from wage income below the contribution ceiling of $2\bar{w}$. Individual pension benefits p_j of a retiree at age $j \geq j_R$ in a specific year are computed from the product of his/ her earning points ep_{j_R} he/ she has accumulated at retirement and the actual pension amount (APA) per earning point:

$$p_j = ep_{j_R} \times APA. \tag{19}$$

The budget of the pension system must be balanced in the long-run. Consequently, we allow in the transitional periods for new pension debt $(1+n)B_{P,t+1} - B_{P,t}$ in order to balance the periodical budgets

$$(1+n)B_{P,t+1} - B_{P,t} = r_t B_{P,t} + PB_t - \tau_t PC_t, \tag{20}$$

where

$$\begin{aligned} PB_t &= \sum_{j=j_R}^{J} \int_{A\times R\times P\times E_j} p_j(z_j, Z_t)\mathrm{d}X_t(z_j) \qquad \text{and} \\ PC_t &= \sum_{j=1}^{j_R-1} \int_{A\times R\times P\times E_j} \min[w_j(z_j, Z_t); 2\bar{w}(Z_t)]\mathrm{d}X_t(z_j) \end{aligned}$$

define aggregate pensions benefits and the contribution base in period t. In the initial long-run equilibrium $B_P = 0$ and the contribution rate τ is computed endogenously. After the reform we adjust the contribution rate once to balance the intertemporal budget.

3.5 Welfare and efficiency calculation

The welfare criterion we use to assess the policy reform is ex-ante expected utility of an agent, before his productivity level is revealed (i.e. looking upon her life behind the Rawlsian veil of ignorance). Similar to (5), expected utility of a newborn in period t is computed from

$$EV(z_1, Z_t) = \int_{E_1} V(z_1, Z_t)^{1-\frac{1}{\gamma}} \mathrm{d}X_t(z_1) \quad \text{with } z_1 = (0, 0, 0, e_1).$$

In order to compare the welfare for a specific individual before and after the reform, we follow Auerbach and Kotlikoff (1987, 87) and compute the proportional increase (or decrease) in consumption and leisure ϕ which would make an agent in the initial equilibrium as well off as after the reform, i.e.

$$EV(z_j, Z_t) = EV(z_j, Z_0, \phi),$$

where

$$V(z_j, Z_0, \phi) = u(c_j(1+\phi), \ell_j(1+\phi)) + \delta \left[\psi_{j+1} EV(z_{j+1}, Z_0, \phi) + (1 - \psi_{j+1}) \mathcal{B}(q_{j+1}(1+\phi)) \right].$$

We can compare all existing cohorts in the reform year Z_1 and all newborn cohorts along the transition path with the respective cohorts in the initial equilibrium Z_0, since they have identical individual state variables. Due to the homogeneity of the utility function (10) and (3.5) we have $EV(z_j, Z_0, \phi) = (1 + \phi)EV(z_j, Z_0)$. Therefore, for all agents living in the initial equilibrium the necessary increase (or decrease) in percent of resources is

$$\left[\frac{EV(z_{j+1}, Z_1)}{EV(z_{j+1}, Z_0)} - 1 \right] \times 100. \tag{21}$$

A value of 1.0 indicates that this agent would need one percent more resources in the initial long-run equilibrium to attain the expected utility level he receives after the policy reform. Within each cohort, we aggregate for each productivity level the percentage changes across asset levels and pension points in order to derive the average (uncompensated) welfare changes for alternative income classes which are reported in the following tables. For newborn generations who enter the labor market during the transition we can only report the ex-ante welfare change for the whole cohort. Consequently, in order to compare the intra-cohort welfare consequences of future born agents, we compute the ex-post welfare change after the initial productivity level has been revealed.

In order to asses the aggregate efficiency consequences, we introduce a Lump-Sum Redistribution Authority (LSRA) in the spirit of Auerbach and Kotlikoff (1987, 62f.) as well as Nishiyama and Smetters (2005, 2007), Fehr and Habermann (2008a) and Fehr et al. (2008) in a separate simulation. The LSRA treats those cohorts already existing in the initial equilibrium and newborn cohorts differently. To already existing cohorts it pays a lump-sum transfer (or levies a lump-sum tax) $v_j(z_j, Z_1), j > 1$, to bring their expected utility level after the reform back to the level of the initial equilibrium $EV(z_j, Z_0)$. Since utility depends on age and state, these transfers (or taxes) have to be computed for every agent in the first year of the transition. Consequently, after compensation, their relative welfare change is zero. Those who enter the labor market in period $t \geq 1$ of the transition receive a transfer $v_1(z_1, Z_t, V^*)$ which guaranties them an expected utility level V^*. Note that the transfers $v_1(z_1, Z_t, V^*)$ may differ among future cohorts but the expected utility level V^* is identical for all. The value of the latter is chosen by requiring that the present value of all LSRA transfers is zero:[6]

$$\sum_{j=2}^{J} \int_{A\times R\times P\times E_j} v_j(z_j, Z_1)\mathrm{d}X_1(z_j) + \sum_{t=1}^{\infty} v_1(z_1, Z_t, V^*)\Pi_{s=1}^{t-1}(1+r_s)^{-1} = 0.$$

In the first period of the transition the LSRA builds up debt (or assets) from

$$(1+n)B_{RA,2} = \sum_{j=2}^{J} \int_{A\times R\times P\times E_j} v_j(z_j, Z_1)\mathrm{d}X_1(z_j) + v_1(z_1, Z_1, V^*)$$

which has to be adjusted in each future period according to

$$(1+n)B_{RA,t+1} = (1+r_t)B_{RA,t} - v_1(z_1, Z_t, V^*). \tag{22}$$

Of course, LSRA assets are also included in the asset market equilibrium condition (27).

Given the compensated expected utility V^* of newborns, we compute the (compensated) relative change in initial resources which would be required in order to attain V^*. If the latter is positive (negative) all households in the reform year who lived in the previous period would be as well off as before the reform and all current and future newborn households would be strictly better (worse) off. Hence, the new policy is Pareto improving (inferior) after lump-sum redistributions.

3.6 Equilibrium conditions

Given the fiscal policy $\Psi_t = \{G, T(y), B_{G,t}, B_{RA,t}, \tau_{c,t}, \tau_{b,t}, \tau_t, \hat{s}, \theta, \omega\} \quad \forall\ t$, a recursive equilibrium path is a set of value functions $\{V(z_j, Z_t)\}_{j=1}^{J}$, household decision rules $\{c_j(z_j, Z_t), \ell_j(z_j, Z_t), s_j(z_j, Z_t)\}_{j=1}^{J}$, distributions of unintended bequest $\{b_j(z_j, Z_t)\}_{j=1}^{J}$, measures of households $\{\xi_t(z_j)\}_{j=1}^{J}$ and relative prices of labor and capital $\{w_t, r_t\}$ so that the following conditions are satisfied $\forall\ t$:

1. Households' decision rules solve the household's decision problem (8) subject to the given constraints (11), (13) and (15).

[6] In order to avoid that transfers have liquidity effects at young ages, they are actually given (with interest) to cohorts when they retire or later. Further information on the computation of V^* is available upon request.

2. Factor prices are competitive, i.e.

$$w_t = (1-\varepsilon)\varrho\left(\frac{K_t}{L_t}\right)^{\varepsilon}, \tag{23}$$

$$r_t = \varepsilon\varrho\left(\frac{L_t}{K_t}\right)^{1-\varepsilon} - \delta_k. \tag{24}$$

3. In the closed economy aggregation holds,

$$L_t = \sum_{j=1}^{J}\int_{A\times R\times P\times E_j}[1-\ell(z_j,Z_t)]e_j\,\mathrm{d}X_t(z_j), \tag{25}$$

$$C_t = \sum_{j=1}^{J}\int_{A\times R\times P\times E_j} c_j(z_j,Z_t)\mathrm{d}X_t(z_j), \tag{26}$$

$$K_t = \sum_{j=1}^{J}\int_{A\times R\times P\times E_j}(\mathrm{a}_j+\mathrm{a}_j^R)\mathrm{d}X_t(z_j) - B_{G,t} - B_{P,t} - B_{RA,t}, \tag{27}$$

   while in the small open economy aggregate capital is derived from (24).

4. The laws of motion (2) and (3) for the measure of households hold.

5. Unintended bequests satisfy

$$(1+n)\sum_{j=1}^{j_R-1}\int_{A\times R\times P\times E_j} b_j(z_j,Z_{t+1})\mathrm{d}X_{t+1}(z_j) = \sum_{i=1}^{J}\int_{A\times R\times P\times E_i} q_{i+1}(z_i,Z_t)(1-\psi_{i+1})\mathrm{d}X_t(z_i). \tag{28}$$

6. The budgets of the government (17), the pension system (20) and the redistribution authority (22) are balanced in the long-run.

7. The goods market clears, i.e.

$$Y_t = C_t + (1+n)K_{t+1} - (1-\delta_k)K_t + G \quad \text{(closed economy)}$$
$$Y_t = C_t + (1+n)K_{t+1} - (1-\delta_k)K_t + G + NX_t \quad \text{(open economy)}$$

   with NX_t as net exports in period t.

3.7 The computational algorithm

Our simulations start from initial steady states which reflect the German social security system. The computation method follows the Gauss-Seidel procedure of Auerbach and Kotlikoff (1987). We start with a guess for aggregate variables, bequest distribution and policy parameters. Then we compute the factor prices and the individual decision rules and value functions. This involves a discretization of the state space which is explained in the appendix. Next we obtain the distribution of households and aggregate assets, labor supply and consumption as well as the social security tax rate and the consumption tax rate that balances government's budget. This information allows us to update the initial guesses. The procedure is repeated until the initial guesses and the resulting values for capital, labor, bequests and endogenous taxes have sufficiently converged.

Next we solve for the transition path where social security is completely eliminated. We assume that the transition between the initial and the final steady state takes $4 \times J$ periods. With alternative policy parameters we assume in the first guess that aggregate values and bequests of the initial equilibrium would remain constant along the transition. Then we update for each period of the transition the individual and aggregate variables until we reach convergence.

4 Calibration of the initial equilibrium

Table 1 reports the central parameters of the model. In order to reduce computational time, each model period covers five years. Agents start life at age 20 ($j = 1$), are forced to retire at age 60 ($j_R = 9$) and face a maximum possible life span of 100 years ($J = 16$). The population growth rate is set at $n = 0.05$ which roughly corresponds to an annual growth rate of 1 percent. Since population growth is close to zero in Germany, this figure mainly reflects labor productivity growth. The conditional survival probabilities ψ_j are computed from the year 2000 Life Tables for Germany reported in Bomsdorf (2003). With respect to the preference parameters we set the intertemporal elasticity of substitution γ to 0.5, the intratemporal elasticity of substitution ρ to 0.6 and the leisure preference parameter α to 1.5. This is within the range of commonly used values (see Auerbach and Kotlikoff, 1987, or Fehr, 1999) and yields a compensated labor supply elasticity of 0.32 in our benchmark. With respect to the time preference rates β and δ we distinguish two combinations which both yield a realistic capital to income ratio. Following Angeletos et al. (2001, p. 54) we assume that the rational consumer (i.e. $\beta = 1$) has a lower discount factor δ than the hyperbolic consumer. In order to calibrate a realistic capital to output ratio, the discount factor for the rational consumer is set at 0.986 which implies an annual discount rate of about 0.5 percent. Next we specify for the hyperbolic consumer $\beta = 0.75$ and set $\delta = 1.005$ in order to calibrate the same capital-output ratio. This calibration strategy follows Angeletos et al. (2001) and İmrohoroğlu et al. (2003, p. 763). While Angeletos et al. (2001) report that $\beta = 0.7$ is typically measured in laboratory experiments, İmrohoroğlu et al. (2003) choose values between 0.6 and 0.9 for

β and calibrate quite similar values for δ. Finally, we specify a bequest parameter $\mu = 0.5$ which yields a realistic bequest level for Germany.

Table 1: Parameter selection

Demographic parameters	Preference parameters	Technology parameters	Government parameters
$J = 16$	$\gamma = 0.5$	$\varrho = 1.5$	$\tau_c = 0.17$
$j_R = 9$	$\rho = 0.6$	$\varepsilon = 0.3$	$\tau_k = 0.1$
$n = 0.05$	$\alpha = 1.5$	$\delta_k = 0.276$	$B_G/ Y = 0.6$
ψ_j :Bomsdorf (2003)	$\beta = 1.00/ \delta = 0.986$		$d(w_j) = 1200 + 0.04w_j$
	$\beta = 0.75/ \delta = 1.005$		$T(y)$, APA see text
	$\mu = 0.5$		

With respect to technology parameters we specify the general factor productivity $\varrho = 1.5$ in order to normalize labor income and set the capital share in production ε at 0.3. The annual depreciation rate for capital is set at 5 percent which yields a periodic depreciation rate of $\delta_k = 0.276$. The annual APA value is chosen in order to derive a replacement rate of net income of 75 percent, which yields a realistic contribution rate for Germany. As already explained, the taxation of gross income (from labor, capital and pensions) is close to the current German income tax code and the marginal tax rate schedule $T05$ which was introduced in 2005. We assume that our households are married couples and apply the German income splitting method. In addition, we consider a special allowance for labor income of $d(w_j)$ which combines a fixed amount of 1200 € and an additional deduction of 4 percent of labor income. Given taxable income y_j the marginal tax rate rises linearly after the basic allowance of 7800 € from 15 percent to maximum of 42 percent when y_j passes 52.000 €. In addition to the income tax payment, households pay a surcharge at rate 5.5 percent in the benchmark. In the initial long-run equilibrium we assume a debt-to-output ratio of 60 percent, fix the consumption and the corporate tax rate at 17 and 10 percent, respectively and compute G endogenously to balance the budget.

In order to model the income process, we distinguish six productivity profiles across the life cycle. Fehr (1999) has estimated five such profiles from data of the German Socio-Economic Panel Study (SOEP). We split up the profile of the lowest income class in order to improve the income distribution. When an agent enters the labor market (at age 20-24) he belongs to the lowest productivity level with a probability of 10 percent, to the second lowest again with 10 percent and to higher levels with 20 percent, respectively. After the initial period, agents change their productivity levels according to the age-specific Markov transition matrices which are reported in the appendix. The latter are also computed from SOEP data for different years between 1988 and 2003. Specifically, we sorted the primary earners of the years 1988, 1993 and 1998 into seven cohorts and divided them within each cohort into six income classes. Then we compiled for each cohort and income class the respective income classes of its members in the surveys of the years 1993, 1998 and 2003 in order to calculate the age-specific transition matrices.

Table 2 reports the calibrated benchmark equilibria with either rational or sophisticated hyperbolic consumers and the respective figures for Germany in 2005. Both equilibria feature a closed economy so that the interest rate is endogenous and the trade balance is zero. Since preferences include a bequest motive, the reported bequest in Table 2 are partly accidental due to missing annuity markets and partly intended as well. The equilibrium for hyperbolic

Table 2: The initial equilibrium

	Rational consumers	Hyperbolic consumers	Germany 2005
Calibration targets			
Pension benefits (% of GDP)	13.1	13.1	12.3[a]
Pension contribution rate (in %)	19.5	19.5	19.5[a]
Tax revenues (in % of GDP)	20.7	20.7	20.2[a]
Capital-output ratio	2.9	2.9	2.9[a]
Other benchmark coefficients			
Interest rate p.a. (in %)	4.0	4.0	–
Bequest (in % of GDP)	6.2	5.7	4.7-7.1[b]
Gini index net income	0.277	0.279	0.299[c]
Gini index wealth	0.554	0.555	0.613[c]
Borrowing constraints (in %)			
age 20-24	40.0	40.0	10.0[d]
age 25-29	14.4	29.0	18.9[d]
age 30-34	6.6	6.6	18.9[d]

Source: [a]IdW (2008), [b]DIA (2002, p. 19), [c]DIW (2005), [d]SAVE survey.

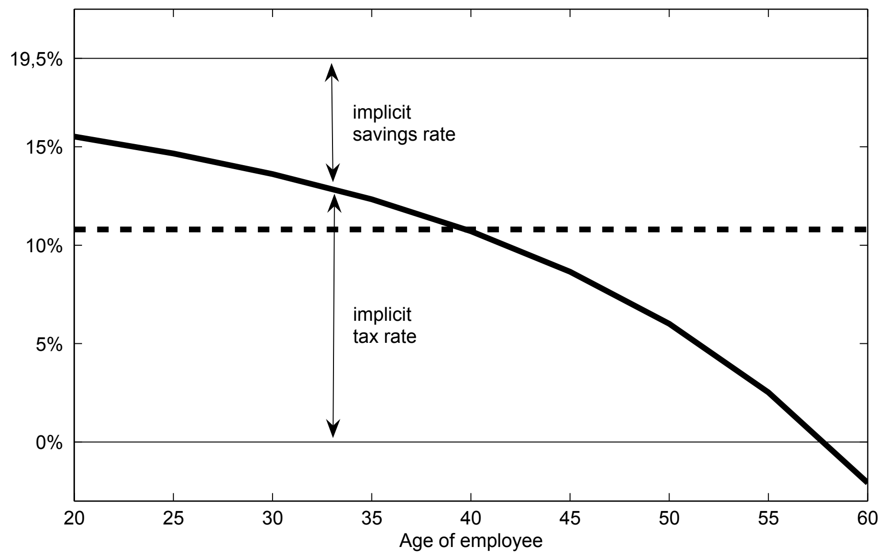
consumers is computed with alternative values for δ and β. Hyperbolic consumers would like to consume more when they are young compared to rational consumers. As a consequence, borrowing constraints hit stronger when young and the bequest share of GDP is slightly reduced.

In both equilibria we hit the target for the pension contribution rate of 19.5 percent. It is useful to split up this contribution rate into its (implicit and age-specific) savings and tax shares. The implicit savings rate τ_j^s of age j is computed by dividing the present value of benefits from one year of average contributions by the present value of average income at the time of retirement[7], i.e.

$$\tau_j^s = \frac{APA \sum_{k=j_R}^{J} \Pi_{i=j_R+1}^{k} (1+r_i)^{-1}}{\bar{w}\, \Pi_{i=j+1}^{j_R} (1+r_i)}. \tag{29}$$

Consequently, by investing at each age j the implicit savings rate in an annuitized plan, the capital market would generate the same income stream as the contributions to the public system, see Sinn (2000). As earning points don't pay any interest, the implicit savings rate increases with rising age. The implicit tax rate is then computed from the difference between the contribution rate of 19.5 percent and the age-specific savings rate, i.e. $\tilde{\tau}_j = \tau - \tau_j^s$ (see the solid line in Figure 1 for both savings and tax rate).

Figure 1: Implicit savings and tax rates



5 Simulation results

This section presents our simulation results. In the first subsection we repeat the policy experiment from Fehr et al. (2008b) and simply eliminate the public pension system. We then combine this reform with an introduction of either voluntary or mandatory retirement accounts. The last subsection presents some sensitivity calculations for alternative preference parameters. If not stated otherwise, all considered reform experiments are simulated in a small open economy.

[7]Fenge, Übelmesser and Werding (2006) present similar calculations for Germany, while Bütler (2002) derives a more general formula.

5.1 Pension funding without IRAs

In order to eliminate the existing pay-as-you-go financed pension system, we simply set $\nu = 0$ in equation (15). Consequently, individuals keep their existing earning points, but do not accumulate additional ones in the future. Current and future pension benefits are financed by a time- (and age-)invariant payroll tax rate, which is computed from the respective intertemporal pension budget. On average, this payroll tax rate reflects implicit taxes of the former PAYG-system, while the reduction reflects the average savings share, see Sinn (2000). Similarly, the intertemporal government budget is balanced by a one-time adjustment of the consumption tax rate. Therefore, annual budgets may include deficits (surpluses) during the transition which are financed by (used to reduce) pension and government debt.

In order to clearly point out the implications of our pure pension funding exercise, Table 3 summarizes the effects of such a reform. There are five major points that come with the elimination of the existing PAYG pension system. First, we make the implicit, age-dependent tax rate of the retirement system explicit and age-independent (see dashed line in Figure 1). As labor supply elasticities usually rise with age, this effect causes higher distortions and therefore a decline in overall labor supply. Second, sizing down tax deductible pension contributions, pension privatization causes a switch from a front- to a back-loaded tax structure. On the one hand, this enforces labor supply distortions, on the other hand, a more progressive tax system increases insurance against idiosyncratic income shocks, which has a positive effect on long-run welfare and overall efficiency. Next, the loss of annuitization provided by the pension system results in a loss of longevity insurance but an increase

Table 3: Different implications of pure pension funding

	Effect	Implication
1.	age-independent payroll-tax	- labor supply distortions
2.	switch from front- to back-loaded taxation	- labor supply distortions - higher insurance provision
3.	loss of annuitization	- loss of longevity insurance - increased bequests - loss of commitment device*
4.	no more mandatory savings	- relax liquidity constraints - loss of commitment device*
5.	missing withdrawal restrictions	- loss of commitment device*

* only applies to hyperbolic consumers

in bequests, whereas the abolition of mandatory savings relaxes liquidity constraints. For hyperbolic consumers, however, annuitization, mandatory savings and withdrawal restrictions constituted a commitment device implicit in the current retirement system. With these implications in mind, we can now take a step forward to our quantitative results.

Table 4 reports the macroeconomic effects of our privatization reform. In order to finance pension claims accumulated in the pre-reform years, a permanent payroll tax of $(19.5 - 8.4 =)$ 11.1 percent is required. As lower payroll taxes are substracted from the income tax base, the consumption tax rate can be permanently reduced by 1.9 percentage points. Due to the shift in the tax structure, labor supply and employment fall by 0.8 percentage points initially. Lowering the payroll tax, the additional income available to employees is saved so that assets increase throughout the transition. Higher savings increase bequest and resources of future generations so that labor supply and employment fall by 4.1 percent in the long run. Due to rising revenues from income taxation, public debt is reduced gradually from 60 to 49 percent of GDP. Pension debt, which covers the difference between (reduced) payroll taxes and benefits for retirees, increases to roughly 223 percent of GDP in the long run.[8] As shown in Table 4, the additional supply of private assets more than compensates the additional demand of the government and the pension system. Consequently, net foreign assets increase from zero to 94 $(= 656 - 49 - 223 - 290)$ percent of GDP which finance an annual trade balance deficit of 3.1 percent of GDP in the long run.

Table 4: Macroeconomic effects of pension funding

	Period	Capital Labor Output^a	Assets^b	Bequest^b	Public debt^b	Pension debt^b	Consumption tax^c	Payroll tax^c
Rational consumers	1	-0.8	351.1^d	6.3	60.0^d	0.0^d	-1.9	-8.4
	3	-0.5	411.2	6.6	58.4	57.7	-1.9	-8.4
	5	-0.7	477.1	7.3	54.2	117.6	-1.9	-8.4
	∞	-4.1	655.9	12.4	49.0	223.2	-1.9	-8.4
Hyperbolic consumers	1	-0.5	351.0^d	5.8	60.0^d	0.0^d	-2.0	-8.4
	3	-0.5	417.7	6.1	59.0	57.2	-2.0	-8.4
	5	-0.9	489.9	6.9	55.4	117.1	-2.0	-8.4
	∞	-4.7	683.4	12.3	51.6	223.9	-2.0	-8.4

^{a}Changes are reported in percentage over initial equilibrium. ^{b}In percent of GDP.
^{c}Changes in percentage points. ^{d} Initial long-run equilibrium.

The results for hyperbolic consumers in the lower part of Table 4 are very similar to those

[8] Braakmann, Grütz and Haug (2007, p. 1173) quantify the implicit debt of the German pension system by roughly 230 percent of GDP.

for rational consumers, however, assets increase slightly stronger than before. This is due to the fact that young hyperbolic consumers discount their very old-age consumption less than rational consumers. Consequently, they value the previously accumulated pension entitlements more than rational consumers and react accordingly with their savings. This finding is in line with the results reported in İmrohoroğlu et al. (2003, 769f.) for a closed economy model, where social security crowds out more capital in the long-run when the economy is populated by hyperbolic consumers instead of rational ones. Note that the impact on savings is much smaller than in Fehr et al. (2008b), where a quite similar reform increased savings from 350 to 750 percent of GDP and public debt from 60 to 83 percent of GDP. Whereas in the previous study capital income was partly exempted from taxation, the full taxation of capital income in the present study dampens capital accumulation and increases income tax revenues at the same time so that debt can be reduced.

Table 5 shows for the two benchmark economies the resulting welfare effects of pension privatization for different cohorts in the reform year and the long run without and with compensation payments from the LSRA. As already explained above, we first compute the welfare changes of agents before their productivity is revealed and then derive an average welfare change for the different productivity types in each cohort of the initial equilibrium. Therefore, Table 5 distinguishes in each cohort between "poor", "median", and "rich" households. "Poor" agents are the 10 percent of the cohort with the lowest realized productivity level, "median" are those 20 percent who realize a medium productivity level and "rich" are those 20 percent of the cohort with the highest productivity.[9] For newborn cohorts along the transition path we are not able to disaggregate ex-ante welfare effects. Consequently, we report in the middle column the ex-ante welfare change of the whole cohort and in brackets the (ex-post) welfare changes for "poor" and "rich" newborn households after their productivity is revealed to them.

Due to the reduction in consumption taxes reported in Table 4, welfare of already retired generations increases up to 0.9 percent of available resources. Note that poor pensioners benefit slightly more than rich pensioners which reflects their higher consumption propensity. Middle-aged generations, on the other hand, are losing up to 2.7 percent, since – given the initial implicit tax rates of Figure 1 – the reform effectively raises payroll taxes for these cohorts (see the discussion of Table 3). In addition, since they retire soon, the eliminated longevity insurance had the highest benefit for these workers. Since poor households experience a steeper increase in marginal tax rates than rich households (who might already be in the top income tax bracket), welfare losses decrease with income level within the middle cohort. Finally, future generations are gaining roughly 2.5 percent in welfare, as payroll tax burdens are reduced and bequests increase. Note that poor households realize especially

[9]For pensioners we aggregate the respective fractions in earning points.

Table 5: Welfare effects of pension funding*

Age in reform year	Rational consumers				Hyperbolic consumers			
	without LSRA			with LSRA	without LSRA			with LSRA
	poor	median	rich		poor	median	rich	
80-84	0.92	0.82	0.73	0.00	0.96	0.87	0.78	0.00
60-64	0.98	0.87	0.76	0.00	1.03	0.91	0.80	0.00
40-44	-2.69	-2.29	-1.29	0.00	-3.25	-2.48	-1.43	0.00
20-24	(1.38)	-0.10	(-0.77)	0.21	(0.00)	-0.91	(-1.00)	-0.82
0-4	(2.55)	1.14	(0.45)	0.21	(1.38)	0.47	(0.30)	-0.82
∞	(3.82)	2.46	(1.87)	0.21	(2.78)	1.91	(1.83)	-0.82

*Changes in percent of resources in initial equilibrium.

strong (ex-post) welfare gains in the long run, since their liquidity constraints are relaxed due to higher bequests and a lower payroll tax rate.

The right part of Table 5 reports the welfare effects in an economy with hyperbolic consumers. We can see that, except for already retired households, welfare decreases compared to the rational consumer case. This basically reflects the value of the commitment device included in the current pension system. Already retired households, on the other hand, do not lose any commitment but still gain from the reduction of the consumption tax rate.

Our long-run welfare results for hyperbolic consumers are in line with the findings of İmrohoroğlu et al. (2003) in the sense that social security decreases welfare even for hyperbolic consumers. However, as already discussed in Fehr et al. (2008b), long-run welfare effects are mainly due to intergenerational redistribution. In order to eliminate these redistributional effects, we simulate the same pension funding reform with a LSRA.[10] The compensated welfare changes for all generations alive in the initial equilibrium are then zero and newborn generations experience identical relative welfare increases. As shown in Table 5, the elimination of social security induces an aggregate efficiency gain of about 0.21 percent of aggregate consumption for rational consumers, which results from relaxed liquidity constraints, a higher insurance provision through the progressive tax system dominating labor supply distortions. In the case of hyperbolic consumers we find an aggregate efficiency loss of 0.82 percent. The difference between both calculations - which amounts to roughly 1 percent of aggregate resources - reflects the value of the commitment technology which implicitly is provided by social security.[11]

[10]We do not report the macroeconomic effects of simulations with compensation payments, but they are available on request.

[11]Fehr et al. (2008b) compute significant efficiency losses in both simulations. The difference is due to the

5.2 Pension funding with IRAs

In this subsection we isolate the different implications of pension funding reported in Table 3 by successively introducing IRAs that exhibit different features of the eliminated pension system. In order to facilitate the comparison with the previous PAYG-system, we assume an individual contribution limit which reflects the reduction in payroll taxes, i.e.

$$\hat{s}_j = -\Delta\tau \times \min[w_j; 2\bar{w}]. \tag{30}$$

Consequently, contributions are restricted to that fraction of labor income, which in the initial equilibrium (on average) was saved in the pension system.[12] In addition, throughout the working phase, withdrawal from IRAs is completely forbidden.

In simulation (1) of Table 6 we introduce withdrawal restricted, front-loaded IRAs that are not annuitized after retirement (i.e. $\omega = 1$). Inheritances from these accounts are taxed at $\tau_b = 0.177$, which equals the average marginal income tax rate. We assume that, similar to public pensions in the benchmark, IRA contributions are tax exempt and withdrawals are fully taxed (i.e. $\theta = 0$). Therefore, we lose effects 2 and 5 from the pure pension privatization experiment (see Table 3), i.e. we don't shift the tax structure to a back-loaded regime anymore. Hence, there is no more increase in insurance provision through a more progressive tax system. For hyperbolic consumers we additionally regain some commitment device by means of withdrawal restrictions during the working phase.

In the short run, labor supply and employment increase for two reasons. First, lack of old age insurance through annuities results in a stronger need for resources at older ages, i.e. especially young households work more in order to finance very old age consumption. Second, medium-aged households who had a high savings share in the pension system in the benchmark, compare Figure 1, now suffer from a cut in resources through the age-independent payroll tax. In order to compensate this reduction and to finance old-age consumption, they have to increase labor supply. Note that, in the reform without IRAs, this effect was dominated by the tremendous change in the tax-structure. Due to higher employment, the payroll tax rate can be reduced by 8.7 percentage points to 10.8 percent. Income tax revenues hardly change in present value terms compared to the initial equilibrium so that consumption tax rates almost remain constant. As before, labor supply falls during the transition due to higher bequest, but now income tax revenues fall during the transition so that public debt

full taxation of capital income and the bequest motive in the present study. The reform shifts the tax structure more towards capital income taxation which improves the insurance provision of the tax system. The bequest motive dampens the welfare loss from eliminated annuity provision.

[12]This is similar to the Stakeholder Pension in the UK and the Registered Retirement Savings Plans (RRSPs) in Canada, see Disney et al. (2009) and Milligan (2003).

Table 6: Macroeconomic effects of IRAs

	Period	Capital Labor Output[a]	Assets[b]	Bequest[b]	IRA share[c]	Public debt[b]	Pension debt[b]	Consumption tax[c,f]
(1) Tax deferred, but not annuitized accounts ($\theta = 0, \omega = 1$)								
Rational consumers	1	1.8	351.1[d]	6.1	0.0	60.0[d]	0.0[d]	-0.1
	3	0.6	419.5	6.6	13.3	58.1	56.9	-0.1
	5	0.2	497.1	7.5	25.2	59.6	116.7	-0.1
	∞	-2.0	706.8	13.7	44.2	82.4	220.4	-0.1
Hyperbolic consumers	1	2.1	351.0[d]	5.6	0.0	60.0[d]	0.0[d]	-0.2
	3	0.9	425.2	6.1	13.6	58.7	56.4	-0.2
	5	0.3	510.6	7.1	25.4	61.0	116.0	-0.2
	∞	-2.4	736.9	13.7	45.4	87.7	220.5	-0.2
(2) Tax deferred and annuitized accounts ($\theta = \omega = 0$)								
Rational consumers	1	1.0	351.1[d]	6.1	0.0	60.0[d]	0.0[d]	0.0
	3	0.5	414.1	6.3	13.6	58.5	57.1	0.0
	5	-0.2	484.5	6.4	25.1	58.8	117.4	0.0
	∞	-0.5	601.3	6.2	42.6	65.9	219.4	0.0
Hyperbolic consumers	1	1.5	351.0[d]	5.6	0.0	60.0[d]	0.0[d]	-0.1
	3	0.7	418.5	5.8	14.0	58.5	56.8	-0.1
	5	-0.1	491.7	6.0	25.7	59.2	116.8	-0.1
	∞	-0.6	610.2	5.5	44.8	67.5	219.2	-0.1
(2b) Mandatory accounts								
Rational consumers	1	1.0	351.1[d]	6.1	0.0	60.0[d]	0.0[d]	0.2
	3	0.1	419.0	6.3	14.2	58.3	57.1	0.2
	5	-0.7	493.8	6.4	26.2	59.2	117.7	0.2
	∞	-1.1	618.1	5.9	45.9	70.2	220.1	0.2
Hyperbolic consumers	1	1.1	351.0[d]	5.7	0.0	60.0[d]	0.0[d]	0.2
	3	0.1	419.2	5.8	14.2	58.1	56.9	0.2
	5	-0.7	493.2	5.9	26.2	58.9	117.6	0.2
	∞	-0.9	613.3	5.4	46.4	69.0	220.6	0.2

[a]Changes are reported in percentage over initial equilibrium. [b]In percent of GDP.
[c]Changes in percentage points. [d] Initial long-run equilibrium. [f] Payroll tax: -8.7 percentage points.

increases significantly. However, since savings rise much stronger than in Table 4, which results from the tax advantages of IRAs, foreign assets are higher in the long run compared to the previous simulation. The share of IRAs in total assets roughly reaches 45 percent in the long run. Note that IRAs are (slightly) more attractive for hyperbolic than for rational consumers which is due to the commitment device provided by restricted withdrawal during employment.

Next, in simulations (2) of Table 6, we introduce accounts which in addition are annuitized after retirement (i.e. $\theta = \omega = 0$), i.e. beneath effects 2 and 5, we also eliminate the loss of annuitization in Table 3. Annuities provide an insurance against longevity but at the same time such assets could not be left to descendants. Given the strong bequest motive of the present calibration, the negative effects dominate so that the IRA share is reduced especially for rational consumers. Since young households now have the possibility to insure against longevity risk through IRA contributions, there is no more need for extra resources at old ages which reduces their labor supply compared to simulation (1). Note, however, that medium-aged consumers still increase their labor supply due to the strong income effect, which results in a moderate increase in employment in the short-run. In the medium and long run, their is no more increase in bequests, which dampens the decrease of labor supply and the increase in assets compared to the previous simulation. Therefore, our results are in contrast to Fuster et al. (2008), where annuitization increases long-run asset accumulation since young generations directly benefit from the insurance provision given to their parents.

Table 7 reports how cohorts contribute to retirement accounts in the new long-run equilibrium. People first have to build up precautionary savings against income uncertainty or would like to borrow against future income. Consequently, younger cohorts in the lowest income class do not contribute to the accounts at all, while only individuals in the top income class save up to the contribution limit. Participation rates increase with age, which is consistent with empirical evidence and the results from Love (2007). Note, however, that low income households contribute much less than middle and high income individuals. In the lowest income class nobody saves up to the contribution limit, whereas on average, up to 50 percent of a cohort contribute as much as possible. Finally, hyperbolic households save more in the accounts, especially at young ages, since they benefit from the commitment technology.

Table 7: Participation in retirement accounts (in %)

	Rational households						Hyperbolic households		
	Lowest income class			All classes			All classes		
Age	$s_j = 0$	$0 < s_j < \hat{s}_j$	$s_j = \hat{s}_j$	$s_j = 0$	$0 < s_j < \hat{s}_j$	$s_j = \hat{s}_j$	$s_j = 0$	$0 < s_j < \hat{s}_j$	$s_j = \hat{s}_j$
20-29	100	0	0	25	45	30	15	45	40
30-39	76	24	0	8	50	42	6	51	43
40-49	33	67	0	3	46	51	2	48	50
50-59	36	64	0	6	49	45	6	50	44

As reported in Boeri, Börsch-Supan and Tabellini (2001, p. 29), especially in Europe many people seem to favor a system of mandatory instead of voluntary accounts. One explanation might be that they want to reduce their own self-control problems. Consequently, in simulations (2b) of Table 6, we additionally make IRA savings mandatory, i.e the individual decision about s_j is completely eliminated and everybody is forced to contribute $\hat{s}_j$ to the accounts. Consequently, only effect 1 of the pension privatization exercise remains, see Table 3. As households now are forced to contribute to IRAs, aggregate savings and especially the IRA share increase compared to the respective benchmark simulation (2), while bequest slightly fall in the long run. Since higher contributions are subtracted from the tax base, income tax revenues fall and the consumption tax rate increases marginally. As contributions now distort labor supply, employment falls more than in the previous simulation (2). Note that the reaction of hyperbolic consumers is slightly dampened compared to rational ones. Since they already contribute more in the accounts voluntarily, they are affected less by mandatory savings.

Table 8 reports welfare and efficiency effects of the simulations with IRAs. Tax deferred and withdrawal restricted accounts in simulations (1) have three central consequences. First, already retired households are hardly affected, since the consumption tax rate now almost remains constant. Second, tax deferral is mostly beneficial for rich households. Consequently, middle-aged rich households lose less than middle-aged poor and median households. Third, compared to Table 5, aggregate efficiency gains decrease slightly for rational consumers, since tax deferral reduces the insurance provision of the tax system. For hyperbolic consumers, however, efficiency losses are substantially lower than in Table 5, since they now benefit from the commitment technology of the IRAs.[13]

When withdrawals from IRAs are annuitized in simulations (2), long-run welfare gains fall due to the reduction of unintended bequest.[14] On the other hand, aggregate efficiency increases significantly, since annuitized accounts now include a longevity insurance formerly provided by social security. Note that the efficiency increase is much stronger for hyperbolic consumers. Annuitization strengthens commitment effects as withdrawals are completely regulated in retirement periods. Since now the IRA system almost provides an identical commitment technology as the original pension system, aggregate efficiency is the same for

[13]We also simulated the introduction of fully taxed IRAs (i.e. $\theta = \omega = 1$). For rational consumers this has no consequences compared to section 4.1, but hyperbolic consumers value the commitment technology due to reduced liquidity and save in IRAs. As a result, the aggregate efficiency loss is reduced from 0.82 percent (in Table 5) to 0.64 percent.

[14]Again, this is in contrast to Fuster et al. (2008) who apply a different preference structure. Fehr and Habermann (2008b) show that in the present model long-run welfare falls due to annuitization as long as the population growth rate is lower than the interest rate.

Table 8: Welfare effects of IRAs*

Age in	Rational consumers				Hyperbolic consumers			
reform	without LSRA			with	without LSRA			with
year	poor	median	rich	LSRA	poor	median	rich	LSRA
(1) Tax deferred, but not annuitized accounts ($\theta = 0, \omega = 1$)								
80-84	0.02	0.02	0.02	0.00	0.09	0.08	0.08	0.00
60-64	0.03	0.02	0.02	0.00	0.10	0.09	0.08	0.00
40-44	-2.68	-2.10	-1.13	0.00	-3.09	-2.10	-0.95	0.00
20-24	(1.52)	0.50	(0.44)	0.13	(0.58)	0.14	(0.64)	-0.29
0-4	(2.62)	1.65	(1.57)	0.13	(1.96)	1.53	(1.96)	-0.29
∞	(3.86)	2.94	(2.95)	0.13	(3.36)	2.98	(3.53)	-0.29
(2) Tax deferred and annuitized accounts ($\theta = \omega = 0$)								
80-84	0.00	0.00	0.00	0.00	0.05	0.04	0.04	0.00
60-64	0.00	0.00	0.00	0.00	0.05	0.05	0.04	0.00
40-44	-1.73	-1.32	-0.79	0.00	-1.89	-1.24	-0.56	0.00
20-24	(2.08)	1.31	(1.50)	0.67	(1.42)	1.34	(2.00)	0.68
0-4	(2.05)	1.27	(1.47)	0.67	(1.33)	1.26	(1.93)	0.68
∞	(1.96)	1.18	(1.37)	0.67	(1.16)	1.09	(1.75)	0.68
(2b) Mandatory accounts								
80-84	-0.10	-0.09	-0.08	0.00	-0.10	-0.09	-0.08	0.00
60-64	-0.10	-0.09	-0.08	0.00	-0.10	-0.09	-0.08	0.00
40-44	-1.89	-1.41	-0.83	0.00	-2.05	-1.45	-0.85	0.00
20-24	(0.22)	0.75	(1.35)	0.02	(0.35)	1.02	(1.74)	0.12
0-4	(0.14)	0.66	(1.26)	0.02	(0.24)	0.90	(1.64)	0.12
∞	(0.00)	0.50	(1.09)	0.02	(0.05)	0.71	(1.44)	0.12

*Changes in percent of resources in initial equilibrium.

rational and hyperbolic consumers. The reported efficiency effects are due to (positive) liquidity effects and higher labor supply distortions. However, the increase in labor supply distortions is fairly small.[15]

With mandatory accounts in simulations (2b), all cohorts are worse off compared to the respective benchmark simulations (2). Of course, since borrowing constraints bite stronger with mandatory contributions, especially poor households experience a welfare loss. Not surprisingly, the introduction of mandatory accounts would completely eliminate the previous aggregate efficiency gain. This also holds for sophisticated hyperbolic consumers who save optimally in self-commiting accounts on their own.[16]

[15] In order to eliminate any labor supply distortions, we simulated the reform (2) with age-specific payroll tax rates computed from (29) and compensate the resulting liquidity effects by lump-sum transfers. Aggregate efficiency gains then increase to 0.75 and 0.79 for rational and hyperbolic consumers, respectively.

[16] Note that it would be no problem to go one step further and also eliminate the last effect of Table 3 by

5.3 Sensitivity analysis

Next we present some sensitivity analysis for the benchmark simulations (2) considered in the previous subsection. We concentrate on rational consumers[17] and assume (if not stated otherwise) a small open economy, i.e. we always start from an equilibrium which features the same interest rate and capital-output ratio as reported in Table 1. Of course, households' savings are different in the initial equilibrium. Consequently, net foreign assets and net exports are non-zero. For a better comparison, in the first line of Table 9, we again report the already explained benchmark results from the previous subsection.

In order to isolate risk aversion from intertemporal substitution, we follow Epstein and Zin (1991) and rewrite the preference structure (9) of the representative consumer by

$$V(z_j, Z_t) = \left\{ u(c_j, \ell_j) + \delta \left[\, \psi_{j+1} EV(\cdot) + (1-\psi_{j+1}) \mathcal{B}(q_{j+1}) \, \right] \right\}^{\frac{1}{1-\frac{1}{\gamma}}}, \quad \text{with}$$

$$EV(\cdot) = \left[\int_{E_{j+1}} V(\cdot)^{1-\eta} \Pi_j(\mathrm{d}e_{j+1}|e_j) \right]^{\frac{1-\frac{1}{\gamma}}{1-\eta}} \quad \text{and} \quad u(c_j, \ell_j) = \left[(c_j)^{1-\frac{1}{\rho}} + \alpha (\ell_j)^{1-\frac{1}{\rho}} \right]^{\frac{1-\frac{1}{\gamma}}{1-\frac{1}{\rho}}}.$$

The parameter η defines the degree of (relative) risk aversion. For the special case $\eta = \frac{1}{\gamma}$ we are back at the traditional expected utility specification discussed above, see Epstein and Zin (1991, p. 266). Consequently, setting relative risk aversion $\eta = 2.0$ yields the benchmark equilibria reported in Table 1 and the welfare effects of Table 5. Typically, values between 1 and 5 for η are perceived as reasonable in the literature, see Cecchetti, Lam and Mark (2000, p. 792) for a discussion.

The considered benchmark reform (2) increases the taxation of precautionary savings (due to higher marginal income tax rates) and shifts the distortion of labor supply from younger towards older ages (due to the flat payroll tax rate). Consequently, precautionary savings are dampened and labor supply is substituted towards younger ages. When we assume in Table 9 that the economy is populated by risk neutral consumers (i.e. $\eta = 0.0$), there is no precautionary savings motive so that, compared to the benchmark (2), mainly regular savings increase. Rising bequests explain higher long-run welfare gains. Higher efficiency gains are due to a stronger liquidity effect, since in the absence of a precautionary savings motive risk neutral consumers are more constrained in the initial equilibrium. Next we return to

employing age-specific tax and contribution rates. With such a reform, there would not be any change in macroeconomic variables and welfare throughout the transition.

[17] Results for hyperbolic consumers are available upon request. The direction of the effects is always the same as for rational consumers. However, aggregate efficiency effects are harder to interpret, since the initial equilibrium now differs considerably.

Table 9: Sensitivity analysis for rational consumers

					Changes in long-run					
η	γ	ρ	μ	open economy	output	regular assets	IRA/ GDP	bequest	welfare	efficiency
2.0	0.5	0.6	0.5	yes	**-0.5**	**-2.2***	**256.7***	**-1.3***	**1.18**	**0.67**
0.0					-0.5	0.9	241.5	1.6	1.27	0.77
	0.33				-0.7	0.5	239.6	2.4	1.74	1.25
		0.1			-0.4	-2.8	265.3	-2.6	1.47	0.93
			0.0		-0.7	-6.8	266.8	-8.9	1.06	0.52
				no	0.8	-1.6	245.7	-3.4	1.38	0.38

* This figure can be computed from the information given in Table 6.

the original assumption about risk aversion and assume that the intertemporal substitution elasticity γ is reduced from 0.5 to 0.33. The optimal consumption profile now becomes flatter so that liquidity constraints in the initial equilibrium are binding stronger and people need less resources at retirement. Consequently, old-age savings in IRAs are shifted towards precautionary savings so that future generations gain significantly due to higher bequests. The higher efficiency gain is due to the stronger liquidity effect. Next we vary the labor supply elasticity and reduce the intratemporal elasticity of substitution ρ from 0.6 to 0.1 in order to approach the fixed labor supply case. Now, goods consumption is stronger bound towards leisure. As a consequence, at retirement – where leisure equals the time endowment – people need more resources so that regular savings are substituted for IRA savings. Although bequests are now reduced compared to the benchmark, long-run welfare as well as efficiency increase due to lower labor supply distortions. Similarly, regular savings are shifted towards IRA accounts, when the bequest motive is eliminated. Bequests fall significantly, but long-run welfare is only marginally reduced, since people benefit from higher longevity insurance. Aggregate efficiency is reduced, since higher IRA savings reduce tax progression so that the insurance provision of the tax system falls. Finally, we turn to the closed economy case where wages increase and the interest rate falls throughout the transition. Of course, higher wages increase the welfare of future generations. However, aggregate efficiency gains are lower compared to the benchmark, since liquidity constraints are reduced less in this case.

6 Discussion

The present paper applies a general equilibrium model with idiosyncratic income risk and liquidity constraints to analyze the substitution of the pension system in Germany by individual retirement accounts. Extending our previous work in Fehr, Habermann and Kindermann (2008) we compute transitional growth and welfare effects as well as aggregate efficiency consequences of pension funding with alternative IRA designs. The following results seem to be important not only for the policy discussion in Germany: First, we quantify the implicit commitment technology embedded in social security by roughly 1 percent of aggregate resources. The commitment technology could be fully included in IRAs if the latter are annuitized. Second, despite the fact that our consumers have an operative bequest motive, welfare gains from the (implicit) longevity insurance of the pension system are significant and range from roughly 0.5 to 1.0 percent of aggregate resources for rational and hyperbolic consumers, respectively. Third, mandatory annuitization does not come without cost. In our model it reduces unintended bequest so that future generations are significantly hurt. Finally, our results highlight the importance of liquidity effects for social security analysis. An IRA system might be able to obtain these efficiency gains without requiring age-specific contribution rates as in Priest (2006) or Hurst and Willen (2007). However, liquidity gains could only be maximized with voluntary and not with mandatory accounts.

Some assumptions of our study deserve specific comments. First, in reality, a complete switch to a funded pension system seems to be hardly practical. Even Chile runs a two-tier system where minimum pensions are financed on a paygo basis. So-called "Riester pensions" in Germany are intended to substitute only a fraction of the public system and all U.S. proposals for an investment-based account system keep a major part of the existing social security. Consequently, our complete privatization exercise mainly serves a pedagogic purpose. Any arbitrary partial privatization would only change the quantitative results, but not our central policy conclusions. Second, in our model, mandatory annuitization is only assumed because it is computationally less demanding. Since annuities could be bought at actuarially fair prices, all individuals would choose to annuitize their retirement savings. Modeling an explicit decision to annuitize as in Brown (2001) or Bütler and Teppa (2007) would require a load factor for annuities (which would be no problem), heterogenous preferences and mortality risks on the household side. This is beyond the scope of the present paper. Third, our analysis could be extended to a more progressive social security system. If the newly established individual accounts eliminate intra-generational redistribution, it is possible to generate additional efficiency gains from reduced labor market distortions. But as shown by Geanakoplos and Zeldes (2008), it is also possible to design progressive accounts which keep the intragenerational redistribution unchanged. In this case our analysis could be directly applied. Finally, it is important to keep in mind that our study abstracts from means-tested minimum pensions. In reality governments guarantee to bail out retirees without resources so that it is optimal for some individuals not to prepare for old age and rely on minimum pensions instead. This so-called prodigality provides a strong case for mandatory pension systems. As Bovenberg and Sørensen (2004) have demonstrated, mandatory savings accounts could overcome the moral hazard problem and improve efficiency if withdrawals are allowed during low income periods. In our future research, we plan to address the problem of means-testing.

Appendix A: Computational method

In order to compute a solution we discretize the state space. The state of a household is determined by $z_j = (\mathrm{a}_j, \mathrm{a}_j^R, ep_j, e_j) \in \mathcal{A} \times R \times P \times E_j$ where $\mathcal{A} = \{\mathrm{a}^1, \ldots, \mathrm{a}^{n_A}\}, R = \{\mathrm{a}^{R,1}, \ldots, \mathrm{a}^{R,n_R}\}, P = \{ep^1, \ldots, ep^{n_P}\}$ and $E_j = \{e_j^1, \ldots, e_j^{n_E}\}$ are discrete sets. We use $n_A = n_R = 20, n_P = 15$ and $n_E = 6$, but we have also simulated the model with more grid points without significant consequences for the reported results. For all these possible states z_j we compute the optimal decision of households from (8). The pension grid is equidistant while the asset grid has increasing intervals between two grid points. Since $u(c_j, \ell_j)$ is not differentiable in every (c_j, ℓ_j) and $V(z_{j+1})$ is only known in a discrete set of points $z_{j+1} \in A \times R \times P \times E_{j+1}$, this maximization problem can not be solved analytically. Therefore we have to use the following numerical maximization and interpolation algorithms to compute households optimal decision:

1. Compute (8) in age J for all possible z_J. Notice that $V(z_{J+1}) = 0$ and households are not allowed to work anymore. Due to the bequest motive, they only have to decide how much they want to bequeath.

2. For $j = J-1, \ldots, 1$:

   Find (8) for all possible z_j by using Powell's algorithm (Press et. al., 2001, 406ff.). Since this algorithm requires a continuous function, we have to interpolate $V(z_{j+1})$. Having computed the data $V(z_{j+1})$ for all $z_{j+1} \in \{j+1\} \times A \times R \times P \times E_{j+1}$ in the last step, we can now find a function sp_{j+1} which satisfies the interpolation conditions

$$sp_{j+1}(\mathrm{a}_{j+1}^k, \mathrm{a}_{j+1}^{R,l}, ep_{j+1}^m) = EV(z_{j+1}) \tag{31}$$

   for all $k = 1, \ldots, n_A$, $l = 1, \ldots, n_R$ and $m = 1, \ldots, n_P$. In this paper we use multidimensional linear interpolation.

Appendix B: Markov transition matrices

Age dependent Markov transition matrices

Age 20-24

		Future productivity level 1	2	3	4	5	6
Current productivity level	1	0.30	0.16	0.27	0.07	0.06	0.13
	2	0.15	0.18	0.19	0.24	0.12	0.13
	3	0.07	0.18	0.39	0.17	0.12	0.08
	4	0.09	0.07	0.15	0.33	0.22	0.15
	5	0.07	0.05	0.13	0.24	0.34	0.17
	6	0.05	0.04	0.10	0.12	0.23	0.46

Age 25-29

		Future productivity level 1	2	3	4	5	6
Current productivity level	1	0.31	0.17	0.22	0.08	0.10	0.11
	2	0.15	0.22	0.28	0.13	0.10	0.11
	3	0.08	0.11	0.33	0.25	0.14	0.09
	4	0.08	0.08	0.21	0.31	0.22	0.09
	5	0.05	0.05	0.12	0.21	0.32	0.24
	6	0.06	0.06	0.09	0.12	0.22	0.46

Age 30-34

		Future productivity level 1	2	3	4	5	6
Current productivity level	1	0.33	0.22	0.21	0.09	0.09	0.07
	2	0.18	0.25	0.30	0.14	0.05	0.07
	3	0.09	0.15	0.35	0.24	0.11	0.06
	4	0.07	0.06	0.24	0.33	0.21	0.09
	5	0.05	0.02	0.11	0.24	0.38	0.20
	6	0.03	0.04	0.05	0.08	0.23	0.58

Age 35-39

		Future productivity level 1	2	3	4	5	6
Current productivity level	1	0.37	0.20	0.22	0.13	0.05	0.05
	2	0.22	0.29	0.32	0.12	0.03	0.02
	3	0.12	0.16	0.38	0.20	0.09	0.05
	4	0.04	0.04	0.24	0.40	0.22	0.07
	5	0.02	0.04	0.07	0.21	0.44	0.22
	6	0.02	0.02	0.04	0.07	0.22	0.63

Age 40-44

		Future productivity level 1	2	3	4	5	6
Current productivity level	1	0.49	0.24	0.15	0.04	0.06	0.02
	2	0.17	0.31	0.36	0.09	0.05	0.03
	3	0.07	0.13	0.40	0.25	0.10	0.05
	4	0.06	0.06	0.20	0.40	0.21	0.08
	5	0.02	0.02	0.09	0.21	0.47	0.18
	6	0.02	0.02	0.05	0.07	0.16	0.66

Age 45-49

		Future productivity level 1	2	3	4	5	6
Current productivity level	1	0.45	0.26	0.22	0.04	0.01	0.01
	2	0.15	0.32	0.33	0.14	0.03	0.03
	3	0.08	0.11	0.44	0.27	0.07	0.02
	4	0.05	0.04	0.16	0.40	0.29	0.06
	5	0.04	0.02	0.08	0.19	0.46	0.20
	6	0.02	0.03	0.05	0.04	0.15	0.70

Age 50-54

		Future productivity level 1	2	3	4	5	6
Current productivity level	1	0.42	0.22	0.21	0.07	0.04	0.04
	2	0.14	0.30	0.35	0.11	0.06	0.04
	3	0.11	0.12	0.37	0.25	0.11	0.03
	4	0.04	0.05	0.19	0.41	0.24	0.07
	5	0.04	0.03	0.09	0.20	0.45	0.19
	6	0.03	0.05	0.07	0.05	0.15	0.66

Source: Authors' own calculations from 1988-2003 SOEP data

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