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Abstract

The present paper studies the growth and efficiency consequences of tax-favored individual retirement accounts in a general equilibrium overlapping generations model with idiosyncratic lifespan and labor income uncertainty. We distinguish between economies with rational and with hyperbolic consumers and compare the consequences of mandatory and voluntary retirement plans with and without annuitized benefits. While a full taxation of capital income yields the highest efficiency gains in the rational consumer model, annuitization and hyperbolic discounting substantially improve the economic efficiency of IRAs. We also show that annuitization alters the intergenerational welfare consequences of the reform substantially, since it reduces accidental bequests. Finally, even if mandatory saving programs have a clear cost advantage, they are only recommendable if consumers are myopic.

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

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1 Introduction

With aging populations and longer life spans, the adequacy of household savings for retirement has become a major policy issue in most developed countries. As successive reforms have reduced the generosity of public pension systems, the need for individual retirement savings has increased during the last decades. Consequently, in order to encourage individuals to save more, many countries have provided special tax arrangements for funds held in occupational and private pension plans. Due to differences in the design and historical introduction of these schemes, their significance still varies considerably across OECD members. In countries such as the United States, United Kingdom, Switzerland or the Netherlands, which either have a long tradition or run a mandatory scheme, the accumulated assets in retirement plans already represent up to 100 percent of GDP. On the other hand, in continental European countries such as Germany, France or Italy, which still run a very generous public pension system, retirement assets in private plans are below 10 percent of GDP. The enormous divergence in terms of asset size, participation rates and program design also reflects the ongoing controversial economic discussion. This paper deals at least with three issues of this debate.

First, we quantify their efficiency and growth effects. Since the tax incentives for retirement savings effectively exempt or even subsidize the return from savings in these plans, they reduce intertemporal at the cost of individual portfolio choice distortions. Consequently, as the discussion in Bernheim (2002) and OECD (2004) indicates, these policies are often considered as an expensive means of encouraging additional saving. While the budgetary cost may even rise in the future, the bulk of contributions is diverted from other sources of savings rather than by reducing consumption.

Second, we analyze the consequences of mandatory annuitization, which is often proposed as a means to overcome or reduce the adverse selection problems on private annuity markets. As discussed, for example, by Finkenstein and Poterba (2002) those who purchase an annuity are likely those who have a longer life expectancy than those who do not. Therefore, annuity prices are too expensive for most individuals. Given this kind of market failure, it seems obvious that individuals should be enticed into locking their funds in a private pension plan that includes the mandatory annuitization of account balances at retirement. However, as pointed out by Pech (2004), subsidized annuity programs may even reduce individual old-age provision in a general equilibrium setting. In addition, individuals may be induced to overannuitize, if the low observed annuity market participation is due to poor health or strong bequest motives, see Inkmann et al. (2007).

Finally, we discuss the issue of mandatory retirement accounts. Whereas in the standard neoclassical life-cycle model individuals are well informed and make the right choices for themselves, there exists a lot of empirical evidence on people's actual savings behavior that does not conform with the standard model, see Bernheim and Rangel (2007) or Mitchell and Utkus (2006). As several studies indicate, a large fraction of the population expresses a lack of self-control which causes a gap between the own actual behavior and the self-reported plans. If households are myopic or behave according to time-inconsistent preferences, they value a commitment device which prevents them to consume to much in the present. Indeed, Boeri et al. (2001, 27f.) find that a mandatory funded pilar has more public support among European citizens than a voluntary supplemental saving program. However, if people are rational and liquidity constrained, mandatory programs may increase borrowing constraints and reduce economic efficiency.

Various studies have already quantified the growth, distributional and efficiency implications of government sponsored retirement accounts with and without annuitization. Already Engen et al. (1994) examine the effectiveness of individual retirement accounts (IRAs) in the US. Applying a partial equilibrium life-cycle model, 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 et al. (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. However, the value of commitment for hyperbolic consumers falls in their model with rising risk aversion. Finally, Pecchenino and Pollard (1997) examine the introduction of actuarially fair annuity products with either voluntary or mandatory contributions in an overlapping generations model with endogenous growth. They show that full annuitization, although individually optimal, may not be socially optimal, since it eliminates unintended bequests and slows down capital accumulation and economic growth below the social optimum.

The present study applies a general equilibrium overlapping generations model which was pioneered by Auerbach and Kotlikoff (1987) and has been recently extended to include mortality and individual income risk as well as borrowing constraints. Private annuity markets are closed by assumption, so that the public sector provides partial insurance against income and longevity risk via the progressive tax system and the unfunded pension system[1]. İmrohoroğlu et al. (1998) evaluate in this framework the long-run consequences of IRAs on the US capital stock for various contribution limits and tax savings instru-

[1]For a recent survey of this literature, see Krüger (2006).

ments. They conclude that about 9 percent of IRA contributions during the 80ies constituted additional savings which raised the US capital stock by about 6 percent. Fuster et al. (2005) extend their framework by introducing mandatory retirement accounts into a model with two-sided altruism where individual life expectancy and income are positively correlated. Starting from a benchmark which reflects the existing US pay-as-you-go social security system, they either eliminate the existing system or substitute halve 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 long run 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. Fuster et al. (2005) also examine the long run welfare effects for different household types. Not surprisingly, households without parents alive prefer a full privatization, since young households benefit less from the longevity insurance while the 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 the parents like to hold annuities during retirement.

Fuster et al. (2005), however, only consider the long-run equilibria. Consequently, the reported welfare effects might be simply due to intergenerational redistribution. In order to distinguish between short and long-run growth and welfare effects of the recent introduction of IRAs in Germany, Fehr et al. (2006a) compute the complete transition to the new long run equilibrium. This allows to quantify the intergenerational welfare consequences and to isolate the insurance and distortionary effects of the considered retirement programs. Like the previous studies our simulations show that tax-favored accounts have a significant impact on long-run capital accumulation and increase the welfare of future generations. However, the latter is mainly due to the fact that the reform will reduce the welfare of elderly and transitional generations. Consequently, the aggregate efficiency gain is almost insignificant for most realistic parameter combinations.

This study extends the previous one in various direction. First, we allow for a richer preference structure which may include hyperbolic discounting and/or a bequest motive. Second, we compare annuitized and non-annuitized benefits at retirement. Third, we distinguish between voluntary and mandatory saving programs and include administrative costs. Finally, we compare alternative financing options in order to balance the government budget. Our simulations confirm the insignificant efficiency effects of the previous study but indicates that annuitization and hyperbolic discounting may substantially improve economic efficiency. We also show that annuitization alters the intergenerational welfare consequences of the reform substantially, since it reduces accidental bequests.

Finally, even if mandatory saving programs have a clear cost advantage, they are only recommendable if consumers are myopic.
In the next section, we describe how we model the tax and benefit system and sketch the structure of the simulation model. Section 3 explains the calibration and simulation approach. Finally, section 4 presents the simulation results and section 5 offers some concluding remarks.

2 The model economy

2.1 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 each date, a new generation is born where we have normalized its size $N_1 = 1$, i.e. we assume zero population growth. Since individuals face lifespan uncertainty with $\psi_j < 1$ the time-invariant conditional survival probability from age $j-1$ to age j, i.e. $N_j = \psi_j N_{j-1}$ and $\psi_{J+1} = 0$.
Our model is solved recursively. Consequently, an agent faces the state vector $z_j = (j, \mathrm{a}_j, \mathrm{a}^R_j, ep_j, e_j)$ where $j \in \mathcal{J} = \{1, \ldots, J\}$ is the household's age, $\mathrm{a}_j \in A = [\underline{\mathrm{a}}, \bar{\mathrm{a}}]$ denotes (liquid) assets held at the beginning of age j, $\mathrm{a}^R_j \in R = [\underline{\mathrm{a}}^R, \bar{\mathrm{a}}^R]$ denotes 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.
Since income is uncertain 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 (i.e. at $j = 1$), the Markov process and optimal decisions. Let $X(z_j)$ be the corresponding cumulated measure to $\xi(z_j)$. Hence,

$$\int_{A\times R\times P\times E_j} \mathrm{d}X(z_j) = 1 \quad \text{for all} \quad j = 1, \ldots, J$$

must hold, as $\xi(z_j)$ is not affected by cohort sizes but only gives densities within cohorts.
In the following, we concentrate on the long run equilibrium and omit the time index t and the state index z_j for every variable whenever possible. Agents are then only distinguished according to their age j.

2.2 Budget constraints and bequests

The budget constraint is defined as follows:

$$\mathrm{a}_{j+1} = \mathrm{a}_j(1+r) + w_j(1-\tau_j) + p_j - s_j - (1+\tau_z)tx_j(y_j, s_j) - (1+\tau_c)c_j + b_j \quad (1)$$

with $\mathrm{a}_1 = 0$ 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, ℓ_j defines leisure consumption and w the wage rate for effective labor. They contribute to or withdraw from IRAs s_j and have to pay progressive income taxes tx_j which depend on taxable income y_j and IRA transactions s_j. Income tax payments are supplemented by a surcharge at rate τ_z[2]. Due to a contribution ceiling the pension contribution rate τ_j depends on income. The price of consumption goods c_j includes consumption taxes τ_c and b_j defines the (accidental or intended) bequests received at age j.
IRA assets accumulate according to

$$\mathrm{a}^R_{j+1} = \mathrm{a}^R_j(1+r_j) + \min[s_j, \hat{s}] - \max[\kappa s_j, 0] \qquad \text{with} \quad r_j = \frac{1+r}{\max[\omega_j, \psi_j]} - 1 \quad (2)$$

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 IRA assets are annuitized at age j, we set $\omega_j = 0$, so that the periodic returns are annuitized, i.e. $r_j > r$. Note that contributions cannot exceed the contribution limit $\hat{s}$. The parameter $\kappa \geq 0$ represents special charges or administrative cost associated with contributions to these accounts. 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, retirees receive a fixed benefit depending on their wealth at the beginning of retirement $\mathrm{a}^R_{j_R}$:

$$s_j = -\frac{(1+r_{j_R})\mathrm{a}^R_{j_R}}{\sum_{j=j_R}^{J} \Pi_{i=j_R+1}^{j}(1+r_i)^{-1}}. \quad (3)$$

Our model abstracts from other annuity markets. Consequently, private assets and non-annuitized IRA 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.

$$b_j = \Gamma_j(e_j) \sum_{i=1}^{J} (1-\psi_{i+1}) N_i \int_{A \times R \times P \times E_i} q_{i+1}(z_i) \mathrm{d}X(z_i) \quad \text{for all} \quad j = 1, \ldots, j_R - 1, \quad (4)$$

[2]This reflects the so-called *solidarity surcharge* in Germany.

where $q_{i+1}(z_i) = (1+r)[\mathrm{a}_{i+1}(z_i) + \omega_{i+1}\mathrm{a}^R_{i+1}(z_i)(1-\tau_b)]$. The age distribution of bequests is computed in the initial steady state where we assume that the heirs always receive the assets of the generation which was 25 years older. Since bequest can be received only during employment, we adjust this rule at the beginning and at 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[3]. Finally, inheritances from IRAs are due to a specific inheritance tax τ_b since they were accumulated tax free.

2.3 Individual preferences and consumer welfare

As usually, the household's preference structure is represented by a time-separable, nested utility function. In order to isolate risk aversion from intertemporal substitution, we follow the approach of Epstein and Zin (1991) and formulate the maximization problem of a representative consumer recursively. In addition to the traditional rational consumer model with time-consistent preferences we also simulate an economy with hyperbolic consumers as İmrohoroğlu et al. (2003). In this section, we explain the computation of time-inconsistent preferences in detail.

Following the seminal work of Strotz (1956) the decision problem of a hyperbolic consumer is modeled 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 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

$$\max_{\hat{c}_{j+1},\hat{\ell}_{j+1},\hat{s}_{j+1}} \left\{ u(\hat{c}_{j+1},\hat{\ell}_{j+1}) + \hat{\beta}\delta\left[\psi_{j+2}E[\hat{V}(z_{j+2})]^{1-\frac{1}{\gamma}} + (1-\psi_{j+2})\mu\hat{q}_{j+2}^{1-\frac{1}{\gamma}}\right]\right\}^{\frac{1}{1-\frac{1}{\gamma}}} \tag{5}$$

with

$$E[\hat{V}(z_{j+2})] = \left[\int_{E_{j+2}} \pi_{j+1}(e_{j+2}|e_{j+1})\hat{V}(z_{j+2})^{1-\eta}\mathrm{d}e_{j+2}\right]^{\frac{1}{1-\eta}}. \tag{6}$$

The parameters γ and η define the intertemporal elasticity of substitution and the coefficient of relative risk aversion, respectively. The (believed) value function $\hat{V}$ of the future is weighted with the survival probability ψ_{j+2} while (believed) bequests are weighted with the bequest motive μ and the probability to die[4]. The expectation operator E in (5) and

[3]De Nardi (2004) highlights the link between individual productivity and inheritance. Fehr et al. (2006a) also report the consequences of alternative bequest distributions.

[4]See De Nardi (2004) and Inkmann et al. (2007) for a similar modeling of bequest preferences.

(6) indicates that future utilities are computed over the distribution of e_{j+2}, i.e. where $\pi_{j+1}(\cdot)$ denotes the age-dependent probability at age $j+1$ to experience productivity e_{j+2} in the next period if the current productivity is e_{j+1}. Note that for the special case $\eta = \frac{1}{\gamma}$ we are back at the traditional expected utility specification, see Epstein and Zin (1991, 266).

Future utility is discounted with the time preference rates δ (long-term) and $\hat{\beta}$ (short-term). The literature distinguishes 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 (i.e. $\hat{\beta} = 1$) despite the fact that they have consistently violated this belief in the past. 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[5]. Consequently, $\hat{c}_{j+1}$, $\hat{\ell}_{j+1}$ and $\hat{s}_{j+1}$ denote the believes of the current self about his future actions. The value function $\hat{V}(\cdot)$ for future beliefs (with $\hat{c}_j, \hat{\ell}_j$ and $\hat{s}_j$ from (5)) is computed for any age $j = 2, \ldots, J$ from

$$\hat{V}(z_j) = \left\{ u(\hat{c}_j, \hat{\ell}_j) + \delta \left[\psi_{j+1} E[\hat{V}(z_{j+1})]^{1-\frac{1}{\gamma}} + (1-\psi_{j+1})\mu \hat{q}_{j+1}^{1-\frac{1}{\gamma}} \right] \right\}^{\frac{1}{1-\frac{1}{\gamma}}}. \tag{7}$$

The current self at age j maximizes the objective function

$$\max_{c_j, \ell_j, s_j} \left\{ u(c_j, \ell_j) + \beta\delta \left[\psi_{j+1} E[\hat{V}(z_{j+1})]^{1-\frac{1}{\gamma}} + (1-\psi_{j+1})\mu \hat{q}_{j+1}^{1-\frac{1}{\gamma}} \right] \right\}^{\frac{1}{1-\frac{1}{\gamma}}}. \tag{8}$$

subject to the budget constraint (1) and $a_{j+1} \geq 0$ and given his believes $E[\hat{V}(z_{j+1})]$ and $\hat{q}_{j+1}$ about the behavior of his future selves. Note that the decision functions $c_j(z_j), \ell_j(z_j)$ and $s_j(z_j)$ denote the actual behavior of the agent. The latter are also used to compute the welfare of the agent, i.e.

$$V(z_j) = \left\{ u(c_j, \ell_j) + \delta \left[\psi_{j+1} E[V(z_{j+1})]^{1-\frac{1}{\gamma}} + (1-\psi_{j+1})\mu q_{j+1}^{1-\frac{1}{\gamma}} \right] \right\}^{\frac{1}{1-\frac{1}{\gamma}}}. \tag{9}$$

The time-inconsistency in preferences is evident from the fact that the $\beta, \hat{\beta}$ terms appear in the decision problems (5) and (8) but not in the calculation of the 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 $\hat{V}$ coincide with the respective functions of the actual behavior c_j, ℓ_j, s_j and V. 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. For naive hyperbolic consumers (i.e. where $\beta < 1$

[5]Of course, it would be no problem to consider also intermediate cases where $\hat{\beta} \in (\beta, 1)$.

and $\hat{\beta} = 1$) the decision and the respective value functions of current and future selves do not coincide so that the computational algorithm has to be specified differently. In the following we only report the results with naive hyperbolic consumers, since for our calibration the results with sophisticated hyperbolic consumers are very similar[6].
The period utility function is defined by

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

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

2.4 The production side

Firms in this economy use capital and labor to produce a single good according to the Cobb-Douglas production technology $Y = \varrho K^{\varepsilon} L^{1-\varepsilon}$ where Y, K and L are aggregate output, capital and labor, 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 $T_k = \tau_k\big[Y - wL - \delta_k K\big]$ where the corporate tax rate τ_k is applied to the output net of labor costs and depreciation. Firms maximize profits renting capital and hiring labor from the households so that the marginal product of capital net of depreciation and corporate taxes equals the market interest rate r and the marginal product of labor equals the wage rate w for effective labor.

2.5 The government sector

Our model distinguishes between the tax system and the pension system. In each period the government issues new debt ΔB and collects taxes from households and firms in order to finance general government expenditures G as well as interest payments on its debt. Whereas government purchases of goods and services G are fixed per capita, we assume a constant debt to output ratio of 60 percent in the benchmark case. Consequently, the long run equilibrium (i.e. where $\Delta B = 0$) the government budget is defined as

$$G + rB = (1 + \tau_z)T_y + \tau_c C + T_b + T_k, \tag{11}$$

where C defines aggregate consumption (see equation (22)) and revenues of income and bequest taxation are computed from

$$T_y = \sum_{j=1}^{J} N_j \int_{A\times R\times P\times E_j} tx_j(y_j(z_j), s_j(z_j))\mathrm{d}X(z_j)$$

[6]Of course, simulation results with sophisticated consumers are available upon request.

and

$$T_b = \tau_b \sum_{j=1}^{J} N_j \int_{A\times R\times P\times E_j} \omega_{j+1}(1-\psi_{j+1})(1+r)\mathrm{a}_{j+1}^R(z_j)\mathrm{d}X(z_j).$$

We assume that contributions to public pensions are exempted from tax while the benefits are fully taxed. Consequently, taxable gross income y_j is computed from gross labor income net of pension contributions and a fixed work related allowance d_w, nominal[7] capital income net of a saving allowance d_s and - after retirement - public pensions.

$$y_j = \max[w_j(1-\tau_j) - d_w; 0] + \max[\tilde{r}(\mathrm{a}_j + \theta_1 \mathrm{a}_j^R) - d_s; 0] + p_j. \tag{12}$$

Although we consider in most simulations that interest income from IRAs is tax exempt (i.e. $\theta_1 = 0$), we also provide for the opposite case (i.e. $\theta_1 = 1$). Given taxable income y_j, we compute the individual income tax payment from

$$tx_j(y_j, s_j) = \mathrm{T05}\big(y_j - \theta_2 \min[s_j - \phi_j(s_j), \hat{s}]\big) - \phi_j(s_j) \tag{13}$$

where T05(.) is the progressive tax code of 2005 in Germany. The parameter θ_2 allows to distinguish between front-loaded and back-loaded taxation of IRAs. If $\theta_2 = 1$ contributions to IRAs are tax exempt up to the contribution limit $\hat{s}$ and withdrawals are subject to taxation. On the other hand, if $\theta_2 = 0$ contributions to IRAs are from taxed income and withdrawals are not taxed. Note that $\theta_1 = 1$ and $\theta_2 = 0$ defines a situation where IRAs have no tax privilege compared to ordinary savings. The function

$$\phi_j(s_j) = \begin{cases} 0/s_j & \text{if} \quad j < j_R \quad \text{and} \quad s_j \le 0 \quad \text{(liquid/illiquid accounts)} \\ -\infty & \text{if} \quad j \ge j_R \quad \text{and} \quad s_j > 0 \\ 0 & \text{else.} \end{cases} \tag{14}$$

allows to distinguish between liquid and illiquid IRAs during employment and to prohibit contributions after retirement. Before retirement (i.e. at age $j < j_R$) withdrawals from IRAs might not be possible, since all the money would be lost if we set $\phi_j = s_j$[8]. After retirement we assume a prohibitive penalty for contributions.

The pension system pays old-age benefits and collects payroll contributions from wage income below the contribution ceiling which is fixed at two times the average income $\bar{w}$. Individual pension benefits p_j of a retiree of age $j \ge j_R$ in a specific year are computed

[7]In order to reflect realistic features of capital income taxation in a model without inflation, we assume for taxation purposes a nominal interest rate $\tilde{r}$, i.e. real interest rate r plus a fictive inflation of two percent per year. The latter exacerbates the distortions of *real* capital income taxation, see Feldstein (1997).

[8]In the following we do not consider intermediate cases with $0 < \phi_j < s_j$. Of course, such an analysis would be possible without any problem.

from the product of his earning points ep_{j_R} the retiree has accumulated at retirement and the actual pension amount (APA) of the respective year:

$$p_j = ep_{j_R} \times APA. \tag{15}$$

In each year of employment, the worker receives an earning point depending on his relative income position $w_j/\bar{w}$ up to the contribution ceiling. Since the latter is fixed at the double of average income $\bar{w}$, the maximum earning points that could be collected per year are 2. Accumulated earning points at age j are therefore

$$ep_{j+1} = ep_j + \min[w_j/\bar{w}; 2], \tag{16}$$

with $ep_1 = 0$.
The budget of the pension system must be balanced in every period. Consequently, the general contribution rate τ is computed from

$$\tau = \frac{\sum_{j=j_R}^{J} N_j \int_{A\times R\times P\times E_j} p_j(z_j)\mathrm{d}X(z_j)}{\sum_{j=1}^{j_R-1} N_j \int_{A\times R\times P\times E_j} \min[w_j(z_j); 2\bar{w}]\mathrm{d}X(z_j)}. \tag{17}$$

Note that due to the contribution ceiling the general contribution rate τ is not necessarily identical with the individual contribution rates in the budget constraint (1). The latter is given by

$$\tau_j = \begin{cases} \tau & \text{if} \quad w_j \leq 2\bar{w}, \\ \tau 2\bar{w}/w_j & \text{if} \quad w_j > 2\bar{w}. \end{cases} \tag{18}$$

2.6 Equilibrium and the computational method

Given the fiscal policy $\{G, B, \tau_k, T05(.), \tau_z, \tau_b, \tau_c, \tau_k, \tau, \phi, \omega, \hat{s}\}$, a stationary recursive equilibrium is a set of bequests $\{b(z_j)\}_{j=1}^{J}$, value functions $\{V(z_j)\}_{j=1}^{J}$, household decision rules $\{c_j(z_j), \ell_j(z_j), s_j(z_j)\}_{j=1}^{J}$, time-invariant measures of households $\{\xi(z_j)\}_{j=1}^{J}$ and relative prices of labor and capital $\{w, r\}$ such that the following conditions are satisfied:

1. given fiscal policy, factor prices and bequests, households' decision rules solve the households decision problem (8);

2. factor prices are competitive, i.e.

$$w = (1-\varepsilon)\varrho\left(\frac{K}{L}\right)^{\varepsilon} \tag{19}$$

$$r = (1-\tau_k)\left[\varepsilon\varrho\left(\frac{L}{K}\right)^{1-\varepsilon} - \delta_k\right] \tag{20}$$

3. in the closed economy aggregation holds,

$$L = \sum_j N_j \int_{A\times R\times P\times E_j} (1-\ell(z_j))e_j \mathrm{d}X(z_j) \tag{21}$$

$$C = \sum_j N_j \int_{A\times R\times P\times E_j} c_j(z_j)\mathrm{d}X(z_j) \tag{22}$$

$$K = \sum_j N_j \int_{A\times R\times P\times E_j} (\mathrm{a}_j + \mathrm{a}_j^R)\mathrm{d}X(z_j) - B \tag{23}$$

$$Q = \sum_j N_j \int_{A\times R\times P\times E_j} \max[\kappa s_j(z_j), 0] dX(z_j) \tag{24}$$

where Q define aggregate administrative cost of IRAs. In the small open economy aggregate capital is derived from (20).

4. Let $\mathbf{1}_{h=x}$ be an indicator function that returns 1 if $h = x$ and 0 if $h \neq x$. Then, the law of motion of the measure of households is, for $j \in \mathcal{J}$,

$$\xi(z_j) = \int_{A\times R\times P\times E_{j-1}} \mathbf{1}_{\mathrm{a}_j=\mathrm{a}_j(z_{j-1})} \times \mathbf{1}_{\mathrm{a}_j^R=\mathrm{a}_j^R(z_{j-1})} \times \mathbf{1}_{ep_j=ep_j(z_{j-1})} \pi_{j-1}(e_j, e_{j-1})\mathrm{d}X(z_{j-1}).$$

5. bequests satisfy

$$\sum_{j=1}^{j_R-1} N_j \int_{A\times R\times P\times E_j} b_j(z_j)\mathrm{d}X(z_j) = \sum_{i=1}^{J}(1-\psi_{i+1})N_i \int_{A\times R\times P\times E_i} q_{i+1}(z_i)\mathrm{d}X(z_i). \tag{25}$$

6. the government budget (11) as well as the budget of the pension system (17) are balanced intertemporally;

7. the goods market clears, i.e.

$$Y = C + \delta_k K + G + Q + NX$$

with NX as net exports.

The computation method follows the Gauss-Seidel procedure of Auerbach and Kotlikoff (1987). For the initial steady state which reflects the current German tax and social security system without IRAs, we start with a guess for aggregate variables, bequests distribution and exogenous policy parameters. Then we compute the factor prices, the individual decision rules and value functions. The latter involves the 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 (or surcharge) rate that balances government budgets. 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.

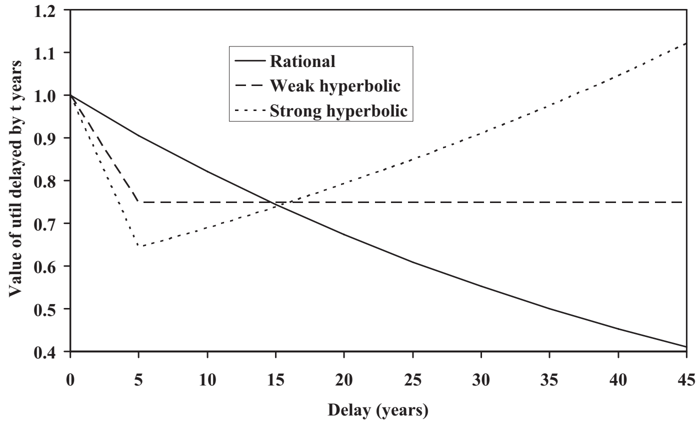
Next we solve for the transition path after the introduction of IRAs. We assume that the transition between the initial and the new final steady state takes $4 \times J$ periods. Given the alternative policy parameters we assume in the first guess that aggregate values and bequests of the initial equilibrium remain constant along the transition. Then we update for each period of the transition the individual and aggregate variables until we reach convergence.

3 Calibration of the initial equilibrium

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 conditional survival probabilities ψ_j are computed from the year 2000 Life Tables 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, the coefficient of relative risk aversion η to 4.0 and the leisure preference parameter α to 1.5. This is within the range of commonly used values (see Auerbach and Kotlikoff, 1987, or Inkmann et al., 2007) and yields a compensated wage elasticity of labor supply of 0.3 in our benchmark. Finally, with respect to the time preference rates β and δ we distinguish two combinations which both yield a realistic wealth to income ratio. Following Angeletos et al. (2001, 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 0.9 which implies an annual discount rate of about 2 percent. Next we specify for the hyperbolic consumer $\beta = 0.75$. In order to calibrate the same capital to output ratio we have to assume $\delta = 1.0$. Angeletos et al. (2001, 54) report that $\beta = 0.7$ is typically measured in laboratory experiments. Figure 1 compares the discount functions and also includes a strong hyperbolic case which is used in the sensitivity analysis.

With respect to technology parameters we chose 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 $\delta_k = 0.06$. The annual APA value is currently about 310 €. We have adjusted this amount slightly in order to derive a realistic standard

Figure 1: Discount functions of exponential and hyperbolic consumers



pension[9] and 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 introduced in 2005. We assume that our households are married couples with a sole wage earner and apply the German income splitting method. In addition, we consider a special allowance for labor income of $d_w = 1200$ € while for capital income the special allowance amounts to $d_s = 3600$ € (per couple)[10]. 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 $\tau_z = 0.055$ in the benchmark. The consumption tax rate is set at $\tau_c = 0.17$ and the corporate tax rate is fixed at $\tau_k = 0.15$. Since the benchmark equilibrium is without IRAs, we set $\hat{s} = 0$.

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 computed also from SOEP data for different years between 1988 and 2003. Specifically we sorted

[9]The standard pension in Germany is computed for a worker who has received an average wage during employment - i.e. $ep_{j_R} = j_R - 1$ - and amounts to roughly 60 percent of net average earnings.

[10]In Germany this allowance is currently 3000 € for nominal interest income, but 6000 € if the source of capital income are dividends.

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 1 reports the calibrated benchmark equilibria with either rational or 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. In addition, we abstract from a bequest motive, i.e. $\mu = 0$. Consequently, the reported bequest in Table 1 are purely accidental since annuity markets are missing. The equilibrium

Table 1: The initial equilibria

	Rational consumers	Naive consumers	Germany 2005*
Pension benefits (% of GDP)	13.1	13.1	12.7
Pension contribution rate (in %)	19.5	19.5	19.5
Tax revenues (in % of GDP)	20.3	20.3	20.0
Average income tax rate (in %)	7.9	8.0	–
Interest rate p.a. (in %)	3.4	3.4	–
Bequest (in % of GDP)	4.3	4.0	5.2
Capital-output ratio	2.9	2.9	3.0
Gini index net income	0.296	0.298	0.299
Gini index wealth	0.540	0.544	0.613
Borrowing constraints (in %)			
age 20-24	20.0	40.0	
age 25-29	7.3	12.5	
age 30-34	5.5	5.5	
age 35-39	4.1	4.2	
age 40-45	2.5	2.3	

*Source: Institut der deutschen Wirtschaft (2006).

for hyperbolic consumers is computed with alternative values for δ and β. Of course, hyperbolic consumers would like to consume more when they are young compared to rational consumers. Therefore, borrowing constraints are more binding for them and the share of constrained consumers in the two youngest cohorts increases from 20 to 40 and from 7.3 to 12.5 percent respectively. In addition, the bequest share of GDP is reduced slightly. The (in this case endogenous) consumption tax rate is again 17 percent. All in all, our calibrated figures match the situation in Germany quite well.

4 Simulation results

This section presents our simulation results when we introduce alternatively designed IRAs into the economy described above. The subsections first explain the modeling of our policy reforms and the computation of their welfare and efficiency consequences. Then we report the macroeconomic and welfare effects of two benchmark simulations. Subsection 3 discusses the aggregate efficiency consequences of alternative reform designs, while the last subsection presents some sensitivity calculations for alternative preference parameters.

4.1 Experimental design and welfare computation

In order to introduce IRAs we have to specify parameters for $\hat{s}, \phi_j, \omega_j, \kappa, \theta_1, \theta_2$ and τ_b and to decide whether contributions are mandatory or voluntary. Since our benchmark simulation reflects the reform design in Germany, we assume a contribution limit which amounts to 8 percent of average income, i.e. $\hat{s} = 0.08\bar{w}$. In addition, we do not allow for early withdrawals and neglect additional administrative cost, i.e. $\phi_j = s_j$ if $s_j < 0$ before retirement and $\kappa = 0.0$. Finally, since we assume deferred taxation of IRAs (i.e. $\theta_1 = 0, \theta_2 = 1$) we tax inheritances from IRAs at $\tau_b = 0.165$, which equals the average marginal tax rate in the benchmark. As in Germany, contributions to IRAs in our benchmark are voluntary. In the German system, individuals can chose between immediate annuitization at the beginning of retirement (i.e. age j_R) and a combination of a fixed payout plan and delayed annuitization. Since the modeling of an optimal withdrawal strategy is not the subject of the present paper[11], we simulate all considered reforms without annuitization (i.e. $\omega_j = 1\, \forall\, j$) and with mandatory annuitization at the time of retirement (i.e. $\omega_j = 1$ if $j < j_R$ and $\omega_j = 0$ if $j \geq j_R$).

The introduction of IRAs affects the tax revenues of the government. In order to finance the revenue losses, we follow the German practice and eliminate the saving allowance (i.e. $d_s = 0$) after the reform[12] and balance the budget intertemporally by computing a time-invariant consumption tax rate τ_c from

$$\tau_c = \frac{B_1 + \sum_{t=1}^{\infty} \left[G - (1+\tau_z)T_{y,t} - T_{b,t} - T_{k,t}\right](1+r)^{1-t}}{\sum_{t=1}^{\infty} C_t (1+r)^{1-t}}.$$

The periodical budget is then balanced by the endogenous debt level, i.e.

$$B_{t+1} = B_t(1+r) + G - (1+\tau_z)T_{y,t} - \tau_c C_t - T_{b,t} - T_{k,t}.$$

[11] See Horneff et al. (2006) or Bütler and Teppa (2006) for a recent analysis of this issue.

[12] However, in Germany the saving allowance was only severely reduced.

Alternatively, we also compute a time-invariant income tax surcharge τ_z which balances the budget intertemporally.
Next we turn to the computation of the welfare changes. The welfare criterion which is applied to assess a reform is ex-ante expected utility of an agent, before the productivity level is revealed. For an agent who enters the labor market the expected utility is computed from

$$E[V(z_1)] = \left[\int_{E_1} \xi(z_1)V(z_1)^{1-\eta}\mathrm{d}e_1\right]^{\frac{1}{1-\eta}}.$$

Note that this formulation is equivalent to (6) since we need to apply the initial distribution $\xi(z_1)$ of the productivity levels.

We assume that the reform is implemented after agents know that they have survived but before the productivity shock is revealed. Consequently, the individual welfare effect is derived from the expected utilities in the initial equilibrium and after the reform announcement. Following Auerbach and Kotlikoff (1987, 87) we compute the proportional increase in consumption and leisure (W) which would make an agent in the baseline scenario as well off as in the reform scenario. If the expected utility level of an age-j individual in year t after the reform is $E[V(z_{j,t})]$ and the expected utility level on the baseline path is $E[V(z_{j,0})]$, the necessary increase (decrease) in percent of initial resources is computed from

$$W_{j,t} = \left[\frac{E[V(z_{j,t})]}{E[V(z_{j,0})]} - 1\right] \times 100 \tag{26}$$

for individuals born before and after the reform. Consequently, a value of $W_{j,t} = 1.0$ indicates that this agent would need one percent more resources in the baseline scenario to attain expected utility $E[V(z_{j,t})]$.
In order to asses the aggregate efficiency consequences, we introduce a Lump-Sum Redistribution Authority (LSRA) in the spirit of Auerbach and Kotlikoff (1987, 65f.) as well as Nishiyama and Smetters (2005) or Fehr et al. (2006a, b). The LSRA pays a lump-sum transfer (or levies a lump-sum tax) to each living household in the first period of the transition to bring their expected utility level back to the level of the initial equilibrium. Consequently, age-j agents who were alive in the initial equilibrium are compensated by the transfers $v_{j,1}(W_{j,1} = 0)$, that depend on their status in the initial equilibrium and guaranty the initial expected utility level $E[V(z_{j,0})]$. On the other hand, those who enter the labor market in period t of the transition receive a transfer $v_{1,t}(W_{1,t} = W^*)$ which guaranties them an expected utility level $E[V(z_{1,t})] = V^*$. Note that the transfers $v_{1,t}$ 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:

$$\sum_{j=2}^{J} N_j \int_{A\times R\times P\times E_j} v_{j,1}(W_{j,1}=0)dX(z_j) + \sum_{t=1}^{\infty} v_{1,t}(W_{1,t}=W^*)N_1(1+r)^{1-t} = 0. \quad (27)$$

With $V^* > E[V(z_{1,0})]$ (i.e. $W^* > 0$), all households in period one who have 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 off. Hence, the new policy is Pareto improving after lump-sum redistributions. With $V^* < E[V(z_{1,0})]$ (i.e. $W^* < 0$), the policy reform is Pareto inferior after lump-sum redistributions.

4.2 Growth and welfare effects of IRAs

Table 2 reports the changes in central variables after the implementation of the reform in period 2005-2009. We distinguish the situation without and with annuitization of account balances after retirement and compare the rational and the (naive) hyperbolic consumer model in a small open economy.

As shown at the bottom of Table 2, the consumption tax rate remains almost constant in all cases considered. Consequently, the elimination of saving allowances almost suffices to finance the revenue shortfalls after the introduction of tax-preferred IRAs. With rational consumers and without annuitization, savings increase in the long run by roughly 9 percent[13]. Additional savings are used to finance the rising public debt (which increases by roughly 20 percent of GDP) and to build up foreign reserves which amount to 14 percent of GDP in the long run. Consequently, capital stock, labor supply and domestic output are hardly affected. The share of IRA savings in aggregate savings rises up to 50 percent. As Table 3 reveals, participation in IRAs rises strongly with age. At young ages, only those with high incomes save in the accounts up to the contribution limit. Low and medium income individuals face a low marginal income tax rate and have to build up liquid precautionary savings first. With rising age liquid precautionary savings increase and more assets are diverted to IRAs in order to take advantage of the favorable tax treatment[14]. The deferred taxation of the accounts also explains the rising public debt. In the medium and long run the government receives higher tax revenues from retirees so

[13]İmrohoroğlu et al. (1998) find a similar increase in the long run capital stock in the closed economy.

[14]Hrung (2002) shows that households first build up precautionary savings against income uncertainty before they invest in IRAs. On the other hand, participation rates seem to decline in many countries before retirement, see OECD (2004, 34).

that the temporary shortfalls could be financed by debt. Of course, higher savings also trigger accidental bequest which rise by more than 16 percent in the long run.

Table 2: Macroeconomic effects of IRAs

	Without annuitization		With annuitization	
	rational	hyperbolic	rational	hyperbolic
	model		model	
Savings[a]				
2010-14	1.2	1.3	1.0	0.4
2015-19	0.8	0.9	0.2	-0.8
2025-29	2.2	2.4	0.3	-1.5
∞	9.2	10.3	3.0	3.3
IRA share in savings (in %)				
2010-14	5.5	6.4	6.3	6.9
2015-19	11.8	13.4	12.9	14.4
2025-29	26.0	29.0	26.1	29.8
∞	44.9	49.3	46.0	53.6
Capital stock/Labor supply/Output[a]				
2005-09	0.3	0.3	-0.1	-0.4
2015-19	-0.2	-0.2	-0.7	-0.8
2025-29	-0.1	0.0	-0.6	-0.6
∞	-0.4	-0.3	0.4	0.5
Public debt[b]				
2010-14	64.4	64.3	65.0	64.6
2015-19	64.7	64.6	65.7	64.8
2025-29	67.5	67.9	68.5	67.1
∞	79.4	81.2	79.4	81.0
Bequest[a]				
2010-14	0.1	0.1	-0.1	-0.3
2015-19	-1.0	-0.9	-3.0	-3.5
2025-29	-0.2	0.2	-12.9	-14.8
∞	16.4	18.8	-45.8	-48.8
Consumption tax rate[c]				
2005-	-0.3	-0.2	-0.2	0.0

[a]Changes are reported in percentage over initial equilibrium. [b]In percent of GDP. [c]In percentage points.

The tax reform increases the tax burden for liquid precautionary savings and reduces the tax burden for illiquid retirement savings. Since young hyperbolic consumers discount retirement consumption less than rational consumers (see Figure 1) they react stronger to this shift in saving incentives. Consequently, their IRA-share is higher and bequest rise stronger than in the simulation with rational consumers.

Annuitized benefits improve the insurance against longevity risk. Therefore, savings rise much slower than in the respective simulation without annuitization[15]. Since people have an additional insurance motive to save in IRAs, the IRA-share rises compared to the respective previous simulations. As the right part of Table 3 shows, agents reshuffle their savings especially in the periods just before retirement into these IRAs. Finally, as one would expect, annuitization reduces bequests significantly in the long run.

Table 3: Long-run participation rate by age group (in %)[a]

	Without annuitization			With annuitization		
Age	$s_j = 0$	$0 < s_j < \hat{s}$	$s_j = \hat{s}$	$s_j = 0$	$0 < s_j < \hat{s}$	$s_j = \hat{s}$
20-24	60	20	20	60	20	20
25-29	49	12	39	43	18	39
30-34	39	6	55	39	6	55
35-39	23	19	58	23	16	61
40-44	18	16	66	16	13	71
45-49	17	13	70	15	11	74
50-54	18	10	72	15	6	79
55-59	22	12	66	10	4	86

[a] Rational consumer model.

Next we consider the short- and long-run welfare effects for different generations and income types. Table 4 compares the model with rational and hyperbolic consumers if benefits from IRAs are not annuitized. The reduction in consumption taxes improves the welfare of all elderly retired generations slightly, since they have only small remaining liquid assets. On the other hand, young retirees, who still have significant private asset holdings at the time of the reform, are burdened by the increase in capital income taxation. Note that the welfare losses rise with incomes due to their higher saving rates and the progressive tax system. Medium, young and future living agents benefit from the tax reductions they receive from savings in IRAs. Future generations receive higher welfare gains due to the rising bequests. Since we compute the welfare changes of newborn and future generations from an ex-ante perspective before their productivity is revealed, we do not distinguish between income levels within a generation. The numbers in brackets report the resulting welfare changes computed from an ex-post perspective. As it turns out, the long run intragenerational welfare effects are not very significant. Next, we compensate all existing elderly and compute an identical welfare level for all newborn and future generations from the budget constraint (27). The aggregate efficiency effect

[15] A similar effect is also found by Pecchenino and Pollard (1997).

reported in the "compensated" column is almost zero. We will discuss this in the next section.

Table 4: Welfare effects of IRAs without annuitization

Age in	rational model				hyperbolic model			
reform		consumers		compen-		consumers		compen-
year	poor	median	rich	sated	poor	median	rich	sated
90-94	0.20	0.17	0.16	0.00	0.15	0.14	0.12	0.00
80-84	0.18	0.16	0.12	0.00	0.14	0.13	0.11	0.00
60-64	-0.05	-0.40	-0.60	0.00	-0.12	-0.51	-0.71	0.00
40-44	0.20	0.06	-0.10	0.00	0.18	-0.03	-0.14	0.00
20-24	(0.15)	0.09	(0.08)	0.04	(0.24)	0.27	(0.35)	0.19
0-4	(0.14)	0.10	(0.07)	0.04	(0.27)	0.27	(0.36)	0.19
∞	(0.28)	0.24	(0.24)	0.04	(0.42)	0.46	(0.54)	0.19

[a]Changes are reported in percentage of initial resources.

The welfare gains (losses) for all existing generations are smaller (higher) in the hyperbolic consumer model. Since the elderly cannot benefit from the tax incentives, the increased taxation of capital income further increases their present bias which in turn dampens welfare. Newborn and future generations, however, are better of in the hyperbolic model than in the rational model. On the one side savings rise stronger which increases intergenerational transfers via accidental bequest. In addition, IRAs provide a commitment technology for hyperbolic agents, since they cannot withdraw from the accounts before retirement. The latter also explains the rise in the aggregate efficiency gain reported in the last column of Table 4.

Table 5: Welfare effects of IRAs with annuitization

Age in	rational model				hyperbolic model			
reform		consumers		compen-		consumers		compen-
year	poor	median	rich	sated	poor	median	rich	sated
90-94	0.15	0.14	0.12	0.00	-0.01	-0.01	-0.01	0.00
80-84	0.14	0.13	0.09	0.00	-0.01	-0.01	-0.02	0.00
60-64	-0.08	-0.44	-0.63	0.00	-0.26	-0.64	-0.82	0.00
40-44	1.31	1.07	0.49	0.00	1.98	1.32	0.50	0.00
20-24	(0.41)	0.40	(0.50)	0.33	(1.14)	1.30	(1.53)	1.63
0-4	(-0.17)	-0.21	(-0.15)	0.33	(0.53)	0.68	(0.87)	1.63
∞	(-0.57)	-0.62	(-0.67)	0.33	(0.17)	0.30	(0.39)	1.63

[a]Changes are reported in percentage of initial resources.

Finally, we turn in Table 5 to the welfare changes when we annuitize the benefits after retirement. Note that in the rational model welfare consequences for elderly are almost the same as in the previous Table 4. Of course, those who are already retired at the time of the reform cannot take advantage of the annuitized accounts since they are not allowed to save there any more. However, medium-aged individuals now gain substantially more than before due to the longevity insurance provision provided by the IRAs. Finally, newborn and future generations are worse of compared to the situation without annuitization and compared to the initial equilibrium before the reform. These generations also benefit from the insurance provision and the tax benefits, but they are hurt by the dramatic reduction of intergenerational transfers from their parents. The introduction of annuities implicitly redistributes income from future generations towards current living ones since the remaining assets of the deceased are not bequeathed to their descendants but to the remaining members of their own generation. Aggregate efficiency, however, increases substantially due to the insurance provision of the new system.

Turning to the right part of Table 5 we note first that now hyperbolic pensioners without private assets are hardly effected by the reform since the consumption tax rate remains almost the same, see Table 2. The stronger welfare increase for medium and younger individuals is due to the fact that annuitized accounts work as a much stronger commitment device than non-annuitized accounts. Hyperbolic agents who can take advantage of that are therefore much better off. Of course, the latter also explains why the efficiency gain in the last column rises strongly.

4.3 Efficiency effects of IRAs

In order to get a better intuition for the aggregate efficiency effects reported in the two previous tables, we discuss in this section the results of alternative reform designs, which share the same initial equilibria of Table 1. In simulation (1) we simply eliminate the saving allowance without introducing IRAs and adjust either the consumption tax or the surcharge rate in order to balance the intertemporal budget. The consumption tax rate falls by 1.9 percentage points, whereas due to the smaller tax base the surcharge rate has to be reduced by 22.1 percentage points (i.e. it turns negative). In the present model with income uncertainty a move from consumption to progressive income taxation increases economic efficiency due to the improved insurance properties of the tax system, see Nishiyama and Smetters (2005). The aggregate efficiency gain is substantially smaller when the surcharge rate is adjusted, since a lower surcharge rate directly reduces tax progressivity. Hyperbolic agents already suffer from a consumption bias towards the present. This distortion is further increased after the elimination of the saving allowance, so that aggregate efficiency either turns negative or is close to zero.

Table 6: Aggregate efficiency effects of IRAs*

Simulation number	IRA design[b] $\hat{s}$	ϕ^a	κ	θ_1	θ_2	mandatory	rational model, endogenous tax τ_c	τ_z	hyperbolic model, endogenous tax τ_c	τ_z
1. $d_s = 0$										
(1)	0.0	–	–	–	–	–	0.47	0.16	-0.09	0.02
2. IRA without annuitization										
(2)	∞	0.0					-0.60	-0.64	0.14	-0.75
(3)	∞						-0.04	0.12	1.00	0.82
(4)	$0.08\bar{w}$	s_j	0.0	0.0	1.0	no	**0.04**	0.01	**0.19**	0.22
(5)	$0.04w$						0.28	0.12	0.13	0.18
(6)	$0.04w$					yes	-0.35	-0.46	-0.07	-0.01
(7)	$0.04w$			1.0	0.0	yes	-0.11	-0.40	-0.11	-0.02
3. IRA with annuitization										
(8)	∞	0.0					0.82	1.22	4.68	4.15
(9)	∞						1.19	1.36	5.09	5.03
(10)	$0.08\bar{w}$	s_j	0.0	0.0	1.0	no	**0.33**	0.32	**1.63**	1.60
(11)	$0.04w$						0.36	0.23	0.75	0.78
(12)	$0.04w$					yes	-0.17	-0.27	0.66	0.70
(13)	$0.04w$		0.12				0.03	-0.12	0.18	0.21

*In percent of remaining resources. [a] For $j < j_R$.
[a]If not stated otherwise, IRA parameters are identical to the benchmark in (4) or (10).

In all following simulations we keep the full taxation of ordinary asset returns. In Simulation (2) we introduce tax-favored accounts without a contribution limit which have the same liquidity as ordinary accounts. Consequently, this reform is just the opposite of the previous one since it effectively eliminates capital income taxation[16]. For rational consumers, the switch to consumption taxation reduces savings distortions but also decreases the insurance properties of the tax system. Since the latter effect dominates, aggregate efficiency is reduced. Hyperbolic consumers value the reduction of intertemporal distortions stronger. Therefore, the positiv effect dominates the negative one so that they experience a slight efficiency gain. A higher surcharge rate increases the distortions

[16]Note, however, that such a reform is only equivalent to an elimination of capital income taxation (i.e. $d_s = \infty$) with proportional income taxes and unlimited tax rebates for negative taxable income.

of labor supply and improves the insurance provision of the tax system. As it seems, the former effect dominates and aggregate efficiency is reduced for rational and hyperbolic consumers.

In simulation (3) we eliminate the liquidity of the IRAs, but keep the unlimited contribution assumption[17]. Consequently, we effectively separate the taxation of capital income according to the savings motive. While liquid assets which are held for precautionary motives are taxed, illiquid assets which are held for old-age are not taxed (or even subsidized). Since precautionary savings have a lower elasticity than old-age savings (see Bernheim, 2002, 1199), this tax discrimination improves economic efficiency compared to simulation (2) in all cases considered[18]. Hyperbolic consumers realize an additional gain since the IRAs provide now a commitment device for them which improves efficiency compared to simulations (1) and (2).

Finally, simulation (4) introduces contribution limits so that we arrive at our benchmark parametrization. The results for the endogenous consumption tax are in bold numbers since they were already reported above. On first sight it seems counterintuitive that the contribution limit even improves aggregate efficiency for rational consumers when the consumption tax is endogenous. However, compared to simulation (3) we proceed now one step further in direction to simulation (1) which yielded the highest efficiency gains. Compared to simulation (3), hyperbolic consumers experience a significant efficiency reduction since their access to the commitment device is now severely restricted.

Next we introduce mandatory contributions in our model. However, in order to facilitate comparison of the efficiency effects between mandatory and voluntary contributions, we assume first in simulation (5) that the contribution limit is reduced to 4 percent of individual incomes up to the income ceiling $2\bar{w}$. For very rich households this has no effect, but for low income individuals, this might severely restrict their contribution choices compared to the benchmark (4). As one can see, this restriction improves overall efficiency compared to the benchmark in the rational consumer model and reduces overall efficiency slightly in the hyperbolic consumer model. Again, the restriction of contributions is efficiency increasing since we move further in direction to simulation (1). In addition, since the contribution limit depends on own labor income, the current set-up works as a labor supply incentive, so that employment considerably increases compared to simulation (4). Of course, this labor supply effect also works in the case of hyperbolic individuals.

[17]Note that this reform design might also reflect retirement accounts with non-binding contribution limits for most savers, such as Rürup accounts in Germany or 401(k) plans in the US.

[18]However, at least for rational consumers it is still more efficient to tax all capital income, see simulation (1).

However, here the negative effect from the stricter contribution limit dominates.
In simulation (6) and (7) we introduce mandatory saving accounts. While we retain the savings incentives in simulation (6), we completely eliminate the latter in simulation (7). Not surprisingly, mandatory programs reduce overall efficiency for rational individuals, since they behave already optimal with a voluntary program. Now they are forced to save when they are liquidity constrained which reduces aggregate efficiency. Note, however, that the welfare reductions from simulation (5) to (6) are much smaller for hyperbolic individuals. Of course, the negative liquidity effect also works for them, but hyperbolic consumers don't save adequate with a voluntary program. Consequently, mandatory programs induce also a positive efficiency effect for them. Finally, we eliminate tax privileges in simulation (7) so that contributions are from already taxed income and interest income from the IRA account is subject to taxation. For rational consumers, this yields a substantial improvement of overall efficiency compared to simulation (6). The difference between simulations (6) and (1) is now only due to stronger binding liquidity constraints.

Next we turn to annuitized accounts after retirement. In order to compare the outcomes with and without annuitization, we repeat the previous simulation exercises. Again, we start in simulation (8) with the assumption that contributions to and withdrawals from IRAs are completely flexible before retirement. After retirement, all wealth held in the account has to be transferred into an annuity contract. Since annuities provide an insurance against longevity which is missing in the benchmark, it is not surprising that aggregate efficiency rises strongly compared to simulation (2). Note, however that the efficiency gains are now much stronger for hyperbolic individuals, since the annuity provides a commitment device for them. As before, the elimination of liquidity in simulation (9) improves aggregate efficiency compared to (8) since it allows a separate taxation of precautionary and old-age savings. However, the positive efficiency effects of the tax separation are now smaller than before, since people have a much stronger preference for the accounts which (implicitly) reduces the elasticity of old-age savings. The introduction of a contribution limit for annuitized accounts in the benchmark (10) has now – in contrast to the simulation (4) above – a strong negative impact on aggregate efficiency, since now the access to the welfare improving annuity market is restricted.
Similarly, the introduction of a individualized contribution limit in simulation (11) now reduces aggregate efficiency in the hyperbolic model substantially, since especially hyperbolic agents value the provision of the accounts and they are severely restricted by the reduced limit. In the last two simulations we compare the impact of administrative cost differences between mandatory and voluntary systems. As above, simulation (12) introduces a mandatory contribution system where 4 percent of the income has to be con-

tributed to an IRA. As above, aggregate efficiency is reduced compared to simulation (11). In simulation (13) we return to the voluntary contribution system but assume that 12 percent of contributions are either wasted for additional administrative cost or constitute a load factor due to adverse selection[19]. Our idea is that a mandatory system would work without such a waste of resources, since all individuals would be compulsory insured. Of course, both simulations yield a lower efficiency gain as the comparable simulation (11). Note however, that in the hyperbolic model the mandatory system outperforms the voluntary contribution system with administrative cost.

This should suffice to get a basic intuition of the derived efficiency consequences. In the following subsection we alter the parametrization of our model in order to test the robustness of the derived results.

4.4 Sensitivity analysis

While the previous subsection has presented various simulations which all started from the same initial equilibrium reported in Table 1, the simulations of this subsection all start from a different initial equilibrium due to changes in the preference parameters. Due to space constraints Table 7 reports only the aggregate efficiency consequences without and with mandatory annuitization. For better comparison, the first line in each part presents again the already explained results from the respective benchmark simulation.

Comparing the results of the sensitivity simulations with the respective benchmark values we first note that the aggregate efficiency effects in the upper part (i.e. without annuitization) are surprisingly robust. Only when we increase the degree of myopia in simulation (4e) aggregate efficiency increases significantly in the hyperbolic model since the value of the commitment technology rises. With mandatory annuitization, parameter changes have significant effects since the accounts are much more attractive and have a stronger impact on individuals and the economy. When we introduce in simulation (10a) an additional (so called "warm glow"or "joy of giving") bequest motive, aggregate efficiency is reduced compared to the benchmark (10) since the longevity insurance provision has a lower value to agents. Since the reform improves the insurance provision of the tax system (due to the taxation of ordinary capital income), the aggregate efficiency gains are smaller with risk neutral individuals in simulation (10b).

Overall, the considered reform introduces distortions in the portfolio allocation and increases the existing labor supply distortions, while long-run intertemporal distortions are

[19] Mitchell et al. (1989) report that such a load factor is very plausible for the U.S. Von Gaudecker and Weber (2004) report similar findings for the German private annuity market.

Table 7: Sensitivity analysis*

Simulation number	Preference parameters μ	η	γ	ρ	rational model	hyperbolic model
1. IRA without annuitization						
(4)	0.0	4.0	0.5	0.6	0.04	0.19
(4a)	0.7				-0.03	0.10
(4b)		0.0			-0.08	0.02
(4c)			0.33		0.06	0.10
(4d)				0.2	0.05	0.16
(4e)	$\beta = 0.6, \delta = 1.1$				–	0.70
2. IRA with annuitization						
(10)	0.0	4.0	0.5	0.6	0.33	1.63
(10a)	0.7				0.10	0.48
(10b)		0.0			0.04	1.11
(10c)			0.33		0.01	0.83
(10d)				0.2	0.66	2.07
(10e)	$\beta = 0.6, \delta = 1.1$				–	3.90

*In percent of remaining resources. τ_c endogenous.

dampened. Consequently, the reduction of the intertemporal substitution elasticity in simulation (10c) yields a lower aggregate efficiency gain compared to the benchmark. For the same reasoning, the reduction of the intratemporal elasticity of substitution in simulation (10d) increases aggregate efficiency compared to the benchmark. Finally and as one would expect, stronger myopia improves aggregate efficiency the most with mandatory annuitization.

5 Discussion

We can sum up the economic consequences of tax-favored retirement accounts financed by capital income taxation with the following conclusions. First, such a reform has a substantial impact on aggregate savings. For our central parametrization, the latter rise by roughly 3 percent in the long run when accounts are annuitized and by about 10 percent when they are not. Annuitized accounts reduce long-run accidental bequest and, consequently, savings of younger generations are dampened. Second, the considered reform is welfare reducing for future generations in the rational model with annuitization. In all other cases considered, long-run welfare increases by about 0.2-0.5 percent of individual resources. Third, the benchmark reform yields an aggregate efficiency gain in all considered settings. This is mainly due to the provision of a longevity insurance and the provision of a commitment device. Consequently, the strongest aggregate efficiency gains of our benchmark amounts to 1.6 percent of aggregate resources when IRAs are annuitized and consumers are hyperbolic. Forth, it turns out that a reduced liquidity of tax-favored accounts does not necessary reduce aggregate efficiency. This is due to the fact that the reduced liquidity allows a separate taxation of different saving motives which improves economic efficiency. Fifth, efficiency effects are very robust without mandatory annuitization. In the other case, they are reduced significantly when a bequest motive is introduced and when individuals exhibit a low risk aversion and a low intertemporal elasticity of substitution. On the other hand, a lower intratemporal elasticity of substitution increases aggregate efficiency gains.

Of course, the already reported simulations could be extended in various directions. For example, we could already annuitize the savings in the accounts before retirement or allow (as in Germany) to split between a lump-sum and an annuitized withdrawal at time of retirement. Both extensions have been implemented in the present model, but they have only very minor effects on aggregate efficiency. Similarly, we have simulated the model in a closed economy without significant changes in aggregate efficiency. Of course, it is also possible to model special incentive schemes for low income households (see Fehr et al., 2006a) and to combine IRAs together with substantial reductions in the unfunded public pension system. Fehr et al. (2006b) find for most cases considered substantial efficiency losses from full privatization of public pensions in the present model. Consequently, policy reforms which combine a partial privatization with the introduction of IRAs will tend to have insignificant efficiency effects.

Other interesting extensions are more complex to implement. For example, the present paper has compared the efficiency consequences of alternative tax regimes for capital income, but it has not derived an optimal tax structure. Due to the different elasticities of alternative saving motives it should be possible to show that a higher taxation of precautionary savings is optimal. Such an analysis of optimal capital income taxation, which also considers the optimal progressivity of the income tax and pension system, is left to future research.

Appendix A: Computational method

In order to compute a solution we have to discretize the state space. The state of a household is determined by $z_j = (j, \mathrm{a}_j, \mathrm{a}_j^R, ep_j, e_j) \in \mathcal{J} \times A \times R \times P \times E_j$ where $\mathcal{J} = \{1, \ldots, J\}, A = \{\mathrm{a}^1, \ldots, \mathrm{a}^{n_A}\}, R = \{\mathrm{a}^{R,1}, \ldots, \mathrm{a}^{R,n_R}\}, P = \{ep^1, \ldots, ep^{n_P}\}$ and $E_j = \{e_j^1, \ldots, e_j^{n_E}\}$ are discrete sets. In this paper we use $J = 16, n_A = n_R = 12, n_P = 5$

and $n_E = 6$, but we have also simulated the model with more grid points without significant consequences for the reported results. The initial values for efficiencies are: $\xi(1,0,0,0,e_1^1) = \xi(1,0,0,0,e_1^2) = 0.1$ and $\xi(1,0,0,0,e_1^3) = \cdots = \xi(1,0,0,0,e_1^6) = 0.2$. 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. This is useful since the value function is heavily curved for low values of assets. 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 $z_{j+1} \in \{j+1\} \times A \times R \times P \times E_j$, 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. Hence, in the optimum households should consume everything they have. If they have a 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 $z_{j+1} \in \{j+1\} \times A \times R \times P \times E_j$ in the last step, we can now find a function sp_{j+1} which satisfies the interpolation conditions

   $$sp_{j+1}(j+1, \mathrm{a}_{j+1}^{k}, \mathrm{a}_{j+1}^{R,l}, ep_{j+1}^{m}) = EV(z_{j+1}) \tag{28}$$

   for all $k = 1, \ldots, n_A$, $l = 1, \ldots, n_R$ and $m = 1, \ldots, n_P$. In this paper we use multidimensional cubic spline interpolation, i.e. $sp_j : \mathcal{S}_3 \times \mathcal{S}_3 \times \mathcal{S}_3 \to \mathbb{R}$, whereas $\mathcal{S}_3$ is the space of all one-dimensional, twice continuously differentiable, piecewise third-order polynomial functions and $\mathcal{S}_3 \times \mathcal{S}_3 \times \mathcal{S}_3$ is its tensor product (cf. Judd (1998, 225ff.)). Further information is available upon request. The multidimensional cubic spline interpolation allows a reduction of n_A, n_R and n_P to only a few points with the same accuracy as multidimensional line interpolation. Therefore, in this paper we have set $n_A = 12$.

Appendix B: Markov transition matrices

Age dependent Markov transition matrices

Age 20-24 — Future productivity level

Current productivity level	1	2	3	4	5	6
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

Current productivity level	1	2	3	4	5	6
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

Current productivity level	1	2	3	4	5	6
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

Current productivity level	1	2	3	4	5	6
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

Current productivity level	1	2	3	4	5	6
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

Current productivity level	1	2	3	4	5	6
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

Current productivity level	1	2	3	4	5	6
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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