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Welfare effects of fiscal policy in reforming the pension system

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Abstract

Most reforms of the pension systems imply substantial redistributions between cohorts and within cohort. Fiscal policy, which accompanies these changes may counteract or reinforce this redistribution. Moreover, the literature has argued that the insurance motive implicit in some pension systems plays a major role in determining the welfare effects of the reform: reforms otherwise improving welfare become detrimental to welfare once insurance motive is internalized. We show that this result is not universal, i.e. there exists a variety of fiscal closures which yield welfare gains and political support for a pension system reform. In an OLG model with uncertainty we analyze two sets of fiscal adjustments: fiscally neutral adjustments in the pension system (via contribution rate or replacement rate) and balancing pension system by a combination of taxes and/or public debt. We find that fiscally neutral pension system reforms are more likely to yield welfare gains. Many adjustments obtain sufficient political support despite yielding aggregate welfare losses and *vice versa*. Furthermore, we point to fiscal closures which attenuate and reinforce the relevance of the insurance motive in determining the welfare effects.

Keywords:

pension system reform, fiscal policy, welfare effects

JEL Classification

C68, D72, E62, H55, J26

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1 Introduction and motivation

Demographic trends observed in many developed and developing countries are unfavorable for traditional, defined benefit social security systems.[1] These trends call for a reform in pensions: systemic and/or parametric. A systemic reform consists of replacing the defined benefit system, financed typically on a pay-as-you-go basis, with a defined contribution, partially or fully funded, often referred to as social security privatization (Diamond 1993, Diamond et al. 2016). Parametric reforms adjust parameter(s) of the existing defined benefit systems: contribution rate, replacement rate or eligibility conditions (e.g. retirement age).

The aggregate welfare effects of parametric and systemic pension system reforms as well as their distribution across cohorts are not obvious. For example, a defined contributions pension system links benefits to contributions, thus yielding efficiency gains because distortions associated with pension system contributions are smaller relative to a defined benefits system. Hence, such a reform entails an efficiency gain. However, if income is subject to idiosyncratic shocks, such a reform also lowers the insurance provided by an inherently redistributive defined benefit system (e.g. Heer 2015). The introduction of funding in the place of pay-as-you-go and parametric reforms induce similar trade-offs.

Although the joint effect on welfare remains an quantitative question, there appears to be a consensus that, in terms of welfare, the insurance loss dominates the efficiency gain. In order to compute the total welfare effect one usually computes net welfare change, i.e. all welfare losses are compensated. In a carefully calibrated study of the US, Nishiyama and Smetters (2007) demonstrate that privatization of the pension system, in general, entails an aggregate welfare gain, but only in a deterministic setup.[2] When intragenerational redistribution is taken into account by augmenting the overlapping generations model with idiosyncratic income shocks, the welfare loss due to lower insurance against adverse income shocks outweighs the efficiency gains (see also Davidoff et al. 2005, Fehr et al. 2008, Harenberg and Ludwig 2016).

The studies in the field differ substantially in how the reforms are financed on the fiscal side.[3] Notably, the fiscal closure generates effects on its own, amplifying or attenuating the original effects of the reform – an observation that did not receive much attention in the earlier literature.[4] For example, if public debt is used to balance the pension system during the reform,

[1]Two major forces put a strain on pension systems: longevity and declining fertility. Both these processes contribute to the dependency ratio increase in the US, Europe, Japan and emerging economies alike (Orszag and Stiglitz 2001, Diamond 2004, Holzmann 2013, Diamond et al. 2016).

[2]The extent of efficiency gain may depend on a number of factors including the extent of time inconsistency (Imrohoroglu et al. 2003, Fehr et al. 2008, Fehr and Kindermann 2010), labor supply (Bagchi 2015), financial market imperfections (Nishiyama and Smetters 2007, De la Croix et al. 2012, Caliendo et al. 2014), aggregate risks (Harenberg and Ludwig 2015), etc. See also reviews by Lindbeck and Persson (2003), Fehr (2009, 2016).

[3]For example, Auerbach and Kotlikoff (1987) adjust the contribution rates, whereas Fehr et al. (2008), Keuschnigg et al. (2012), Fehr and Kindermann (2010), Ludwig and Vogel (2010) interchangeably employ tax and contribution rate adjustments. By contrast, Nishiyama and Smetters (2007) use a consumption tax and Okamoto (2005) uses a lump-sum tax. Table A1 summarizes examples of the studies devoted to parametric and pension system reforms, synthesizing the stark differences in the fiscal closures used.

[4]Reportedly, this literature focuses on fundamental questions – e.g. fiscal stability of the pension system, welfare, political support – leaving aside "technicalities" such as fiscal closures (Lindbeck and Persson 2003,

the fiscal costs need not be concentrated among the cohorts living at the time of the reform. By the same token, the use of capital income will amplify the effects of pension privatization on efficiency, whereas increasing the progressivity of the income taxation will partially make up for the loss of insurance that was present in the defined benefit pension system, but is absent after the reform. In this paper we study the interaction between pension system reform and such fiscal closures.

To address this problem, we build an overlapping generations model, calibrated to the US economy. The economy is subjected to longevity and declining fertility, following the projections for the US economy. In the initial steady state, the economy has a defined benefit system financed on a pay-as-you-go basis. If the US economy is to continue with such system, the size of fiscal adjustment for the US economy may indeed be large. Some papers argue that the necessary adjustment to provide for pension system imbalance requires an increase in taxation by roughly 40% (Braun and Joines 2015) or a 40% reduction in replacement rates to maintain the fiscal neutrality of the pension system (Fehr 2000). Such a substantial increase in taxes would have immediate welfare effects (e.g. Kotlikoff et al. 1999, Huggett and Ventura 1999, Genakoplos et al. 2000).

Our model economy is subject to an unexpected systemic change in the pension system. We introduce a defined contribution system with partial funding. This type of reform was recommended as a mean to address fiscal instability resulting from longevity; it has eventually been implemented as of 1990's in many countries around the world (e.g. Central Europe, Mexico, Sweden and Chile, among others, see Holzmann 2013). It is also under consideration in the US economy (Feldstein 2005). In order to study the potential for an additional efficiency gain, we introduce capital income taxation as a fiscal closure for this pension system reform. In order to study the potential for introducing an alternative insurance mechanism, we rely on progressive income taxation as a fiscal closure. None of these closures has been studied previously in the literature. Notably, they both deliver aggregate welfare gains and can obtain sufficient political support. To relate our findings to the literature, we also study the fiscal closures considered by the earlier literature. First, we consider the closures which contain all the transition costs in the pension system: we adjust contribution rates, or pension benefits. Second, we also consider the closures in which the government needs to finance pension system imbalances: we adjust consumption tax rate, labor tax rate, both with and without simultaneous public debt adjustment.

We find that the welfare effects differ substantially across the fiscal closures analyzed in the earlier literature, which hints that even these more conventional closures amplify or attenuate the original effects of the reform. Unlike the earlier literature, we also allow for the closures to differ between the baseline and the reform scenario. Even with these conventional fiscal closures we are able to find closures which yield an overall improvement in welfare and obtain sufficient political support for the reform to be implemented in the initial steady state. Hence, we demonstrate important exceptions from the result accepted as quite universal Davidoff et al.

Fehr 2009).

(2005), Nishiyama and Smetters (2007), Fehr et al. (2008), Harenberg and Ludwig (2016). Indeed, the welfare effect of the insurance loss in the pension system need not dominate the welfare effect of the efficiency gain.

Our analysis provides also several novel results. The closures preferred in the short run, and thus favored politically by the living cohorts, are not necessarily the ones which yield largest long-term welfare gains. In fact, in our calibration, there is sufficient policy support for those policy options which make reforms detrimental to welfare in the long run. Specifically, the standard closures discussed in public debates and analyzed in the earlier literature – such as consumption and labor taxation – obtain sufficient public support if additional smoothing by public debt is allowed for, even though they yield negative aggregate welfare effects. By contrast, genuinely beneficial policies typically considered politically infeasible – such as reduction in benefits or an increase in contribution rates – deliver aggregate gains and may, in fact, obtain sufficient political support in our setup, despite the aforementioned doubts.

Our paper provides three contributions to the literature. First, we demonstrate that pension system reform should be considered in conjunction with the fiscal policy that accompanies it, because fiscal policy may largely amplify or attenuate the original effects of the reform, hence affecting its evaluation. We provide a broad overview for the welfare implications of making pension system solvent with a variety of fiscal instruments – they were typically considered in isolation by earlier studies. Second, we propose two previously unstudied fiscal closures which both improve welfare and secure sufficient political support, hence contesting the earlier result that, under uncertainty, social insurance motive dominates the efficiency gains. These fiscal closures are: capital income taxation (which amplifies the efficiency gains of the reform) and labor income tax progressivity (which partially substitutes the reduction in insurance due to a lack of redistribution in the pension system). Third, we decompose the overall welfare effect of the reform into the one associated with the efficiency gain and the one associated with the loss of insurance against income risk provided by defined benefit pension systems.

The paper is structured as follows. The theoretical model is presented in section 2, while section 3 describes calibration and the simulation scenarios in detail. We present the results in section 4. The final section concludes, emphasizing the contribution to the literature and the policy recommendations emerging from this study.

2 Theoretical model

We build a general equilibrium, overlapping generations model with idiosyncratic income shocks and thus *ex post* within cohort heterogeneity. In the baseline scenario an economy follows a pay-as-you-go (PAYG) defined benefit (DB) system. The economy is subjected to longevity. As a population lives longer, the deficit in the PAYG DB pension system grows.

In the reform scenario, we gradually replace PAYG DB with a partially funded defined contribution (DC) pension system. The key feature of the DC pension system is that, by construction, aging implies no fiscal adjustments to the net position of the pension system.

The gradual implementation of partially funded DC in the place of PAYG DB implies that this fiscal relief is not immediate.

Population dynamics Agents live for $j = 1, 2..., J$ periods and are heterogeneous with respect to age j, one period corresponds to 5 years. Agents are born at the age of 20, which we denote $j = 1$ to abstract from the problem of the labor market entry timing as well as educational choice. Consumers face age and time specific survival rates $\pi_{j,t}$, which is an unconditional survival probability up to age j in period t. At all points in time, consumers who survive until the age of $J = 20$ die with certitude. The share of population surviving until older age is increasing, to reflect changes in longevity. The data for mortality comes from the United Nation projection until 2100. Number of births come from the U.S. Census Bureau projection until 2060. Population eventually becomes stationary, in the final steady state the yearly population growth amounts to 1.002.[5]

Agents have no bequest motive, but since survival rates $\pi_{j,t}$ are lower than one, in each period t certain fraction of cohort j leaves unintended bequests, which are distributed within the cohort. The agent discounts future with time preference parameter δ and conditional probability of survival $\pi_{j+1,t+1}/\pi_{j,t}$.

Budget constraint Agents at an age lower than the retirement age earn labor income $\omega_{j,t}w_t l_{j,t}$, where w_t is the marginal aggregate productivity of labor, $l_{j,t}$ denotes labor supply and $\omega_{j,t}$ is idiosyncratic component of labor productivity, discussed later. Labor income is subject to social security contribution τ_t and labor income tax $\tau_{l,t}$. In addition to salary, income also consists of after-tax capital gain $(1 - \tau_{k,t})r_t a_{j,t}$ (with τ_k denoting capital income tax, r_t the interest rate and $a_{j,t}$ denoting assets accumulated at age j) as well as pension benefits $b_{j,t}$, which agents receive once they reach retirement age. There is no income tax on pension benefits. Moreover, agents receive unintended, cohort specific bequest $\Gamma_{j,t}$. Income is used to purchase consumption goods $(1 + \tau_{c,t})c_{j,t}$ (with $\tau_{c,t}$ denoting tax on consumption) and accumulate assets $a_{j+1,t+1}$. Assets markets are incomplete; only assets with risk free interest rate r_t are available. Each individual also pays a lump sum tax or receives a subsidy Υ_t. Hence, agents face the following instantaneous budget constraint:

$$a_{j+1,t+1} + (1 + \tau_{c,t})c_{j,t} + \Upsilon_t = (1 - \tau_{l,t})(1 - \tau_t)w_{j,t}l_{j,t} + b_{j,t} + (1 + r_t)\, a_{j,t} + tr_{j,t} + \Gamma_{j,t}. \quad (1)$$

The relation between pension system contributions and pension depends on the pension system and is described later. We denote by $tr_{j,t}$ the transfers received at age j at the time t as a consequence of post-reform redistribution of welfare. Naturally, $\forall_t \forall_j tr_{j,t} = 0$ in the baseline scenario. The details about the calculation of $tr_{j,t}$ are discussed later in this section.

[5]Due to the 5 year period, population growth is recalculated and model input is $n = 1.0104 = 1.002^5$

Intra-cohort heterogeneity Each agent is born with an identical labor productivity $\omega_{1,t} = 1$, for all t. However, productivity evolves over time according to the following formula, $\omega_{j,t} = e^{\eta_{j,t}}$, where a random component $\eta_{j,t}$ follows an AR(1) process with persistence parameter ϱ and $\varepsilon_{j,t} \sim \mathbf{N}(0, \sigma^2)$.

$$\eta_{j,t} = \varrho\eta_{j-1,t-1} + \varepsilon_{j,t} \tag{2}$$

As is standard in the literature, we approximate the process above by a first order Markov chain with a transition matrix $\Pi(\eta_{j,t}|\eta_{j-1,t-1})$.

Pension system In the initial steady state, there is a PAYG DB pension system with an exogenous contribution rate τ and an exogenous replacement rate ρ. The actual value of the old age pension benefit for a cohort retiring in period t is computed with reference to average (net) wage of $\bar{J} - 1$ years old in that period, where $\bar{J}$ denotes retirement age. Since pension benefits do not depend on individual lifetime earnings profiles, they provide insurance against idiosyncratic income shocks during the working period. In the PAYG DB system, penions are given by the following formulas

$$b_{j,t+j-\bar{J}} = \rho \cdot w_{avg,t} \prod_{i=1}^{j-\bar{J}} (1 + r^I_{t+i}) \quad \forall j \geqslant \bar{J}, \tag{3}$$

where $r^I_t = \frac{w_t L_t}{w_{t-1} L_{t-1}} - 1$ denotes the payroll growth rate and L_t aggregate labor supply.

The budget constraint of the pension system is given by

$$\sum_{j=\bar{J}_t}^{J} N_{j,t} b_{j,t} \quad = \quad \tau_t w_t L_t + subsidy_t, \tag{4}$$

where $subsidy_t$ denotes the pension system deficit (negative in the case of actual surplus) which, if necessary, is financed by the government. The economy continues with this PAYG DB in the baseline scenario. We assume that the pension system in the baseline scenario provides equal benefits to all agents within cohort, which is much more equitable than the actual pension system in the US. However, from the point of view of our study, this assumption is conservative in a sense that the scope of insurance provided by the baseline pension system is maximal possible. Therefore, in welfare analysis, we obtain an upper bound on welfare loss due to the insurance motive.

In the reform scenario we introduce a partially funded DC system. The reform creates a two-pillar system. In the PAYG pillar of the DC system the contributions are used to finance the contemporaneous benefits, whereas in the funded DC pillar the contributions accrue to individual pension savings. The notional value of the contributions and the funded account are converted to an annuity at retirement.

Implementation is gradual. Individuals born in the year of reform and later participate fully in the reformed DC pension system. However, individuals retired before the introduction of the reform or soon thereafter have their pensions disbursed by the old DB pension system. Hence, for a period of time, a share of the contributions that goes to the DC PAYG pillar is used to finance the contemporaneous DB pension benefits. Consequently, the reform generates a deficit in the pension system that requires financing.

The reform does not change the overall contribution rate relative to the PAYG DB baseline scenario: $\tau_t = \tau_t^I + \tau_t^{II}$, where we denote by τ_t^I the obligatory contribution that goes into the DC PAYG pillar and, by τ_t^{II} the mandatory contribution that goes into the funded pillar. The split of the contribution to the two pillars may be of any proportion. In the simulation, once the reform is fully implemented and in the final steady state, we assume that $\tau_t^I = \tau_t^{II} = 0.5\tau_t$.

The PAYG pillar and the funded pillar provide pension benefits denoted by b^I and b^{II}, respectively. The budget constraint of the PAYG pillar of the pension system is given by

$$\sum_{j=\bar{J}_t}^{J} N_{j,t} b_{j,t}^I = \tau_t^I w_t L_t + subsidy_t, \tag{5}$$

where $subsidy_t$ denotes the pension system deficit (if negative, surplus) which, if necessary, is financed by the government. In the PAYG pillar, during the working period, agents accumulate a notional value of the contributions:

$$f_{j,t}^I = (1 + r_t^I) f_{j-1,t-1}^I + \tau_t^I \omega_{j,t} w_t l_{j,t}, \tag{6}$$

which is converted to an annuity at retirement according to:

$$b_{\bar{J}_t,t}^I = \frac{f_{\bar{J},t}^I}{\sum_{s=0}^{J-\bar{J}} \frac{\pi_{\bar{J}+s,t+s}}{\pi_{\bar{J},t}}} \quad \text{and} \quad \forall_{j>\bar{J}} \;\; b_{j,t}^I = (1 + r_t^I) b_{j-1,t-1}^I. \tag{7}$$

Pensions are directly linked to the contributions which depend on income subject to idiosyncratic shocks, which means that in the PAYG DC pillar the income risk carries over to the pension benefits, eliminating the insurance motive present in the Beveregian PAYG DB system. Since agents see the link between contributions and pensions, their contemporaneous intra-temporal choice is less distorted, i.e. they fully internalize the effects of their labor supply choice throughout the lifetime. The same applies to the funded pillar, in which they accumulate pension funds, which are converted to an annuity at retirement, according to:

$$f_{j,t}^{II} = (1 + r_t) f_{j-1,t-1}^{II} + \tau_t^{II} \omega_{j,t} w_t l_{j,t} \tag{8}$$

$$b_{\bar{J}_t,t}^{II} = \frac{f_{\bar{J},t}^{II}}{\sum_{s=0}^{J-\bar{J}} \frac{\pi_{\bar{J}+s,t+s}}{\pi_{\bar{J},t}}} \quad \text{and} \quad \forall_{j>\bar{J}} \;\; b_{j,t}^{II} = (1 + r_t) b_{j-1,t-1}^{II}. \tag{9}$$

The funded pillar invests the funds, hence the return is given by the market interest rate, while in the PAYG DC pillar it is the payroll growth rate. The savings in the public system are exempt from capital income tax.

We introduce the DC scheme beginning in 2015. All cohorts older than 50 at the time of the reform ($j > 6$ at $t = 2$) remain in the PAYG DB pension system. For the transition cohorts who worked prior to the implementation of the reform and are shifted to the new scheme, we impute the initial values of $f^I_{j,2}$. This imputation is performed for the cohorts born between 1965-1995. We impute the counter-factual funds using the contribution rate τ from the initial steady state and the formula:

$$\forall j \leqslant 6 \quad \text{at} \quad t = 2 \quad f^I_{j,2} = \sum_{s=2}^{s=j} \tau w_1 \bar{l}_{s,1} (1 + r^I_1)^{j-s+1} \tag{10}$$

where $j = 6$ corresponds to the maximum age of agents assigned to DC scheme, once the reform is implemented, and $\bar{l}_{s,1}$ is the average labor supply of cohort s at time 1. Note that these imputed incomes are deterministic, as if the past – prior to the implementation of the pension system reform – had no idiosyncratic income shocks. Hence, for the transition cohorts, the insurance motive is preserved in the pension system. Cohorts born in 1965 and later participate fully in the new, two-pillar DC system. The deficit of the PAYG DC pillar, the $subsidy_t$ in equation (4), is financed by the government. The funded part is balanced by construction.

Consumer problem An individual state of each agent $s_{j,t}$ can be summarized by the level of private assets $a_{j,t}$, pension funds $f_{j,t} = f(^I_{j,t}, f^{II}_{j,t})$ and individual productivity determined by $\eta_{j,t}$, $s_{j,t} = (a_{j,t}, f_{j,t}, \eta_{j,t}) \in \Omega$. An agent enters the economy with no assets ($a_{1,t} = 0$) and the agent at the state $s_{j,t}$ maximizes the expected value of the lifetime utility. We define the optimization problem of the consumer in a recursive form as:

$$V_{j,t}(s_{j,t}) = \max_{c_{j,t}, l_{j,t}, a_{j+1,t+1}} u(c_{j,t}, l_{j,t}) + \delta \frac{\pi_{j+1,t+1}}{\pi_{j,t}} \mathbf{E}\big(V(s_{j+1,t+1}) \mid s_{j,t}\big) \tag{11}$$

subject to the budget constraint given by equation (1), formulas for pensions given by (3) or (7) and (9), depending on the pension system, and the productivity process given by equation (2). The total time endowment is normalized to one. Consumer in our model derives instantaneous utility from consumption and leisure, as given by:

$$u(c_{j,t}, 1 - l_{j,t}) = \log(c_{j,t}) + \phi \log(1 - l_{j,t}). \tag{12}$$

The government In our model, there are four types of taxes: labor income, capital income, consumption and lump sum tax. Tax revenue or change in public debt D_t is used to finance spending on public goods and services G_t, balance the pension system, and service debt $r_t D_{t-1}$, with $\Delta D_t \equiv D_t - D_{t-1}$. We assume that *per capita* public spending is growing at the rate of labor augmenting exogenous technological progress z_t, i.a. $G_t = g_t \sum_{j=1}^{J} N_{j,t}$ and $g_t = z_t g$.

$$G_t + subsidy_t + r_t D_t = T_t + \Delta D_t, \tag{13}$$

$$T_t = \tau_{l,t}(1-\tau_t)w_t L_t + \tau_{k,t} r_t A_t + \tau_{c,t} C_t + \Upsilon_t \sum_{j=1}^{J} N_{j,t}, \tag{14}$$

where C_t and A_t denote, respectively, aggregate labor supply and aggregate assets. We set the initial debt D_t at par with the data to 60% of GDP. The final steady state debt to GDP ratio is the same, to avoid welfare effects stemming from permanent change in public debt ratio.

In order to redistribute efficiency gains (losses) generated by the pension system reform, our model features a Lump Sum Redistribution Authority (LSRA). LSRA makes a lump-sum transfers or collects taxes across all generations. The aggregated net present value of those transfers and taxes across time and cohorts equals to zero.

$$\sum_{t=0}^{\infty}(\prod_{i=t}^{\infty}\frac{1}{r_i})\sum_{j=1}^{J} N_{j,t}\int_{\Omega} tr_{j,t}(s_{j,t})d\mathbb{P}_{j,t} = 0 \tag{15}$$

Production Using capital and labor, the economy produces a composite consumption good. Production function takes a standard Cobb-Douglas form $Y_t = K_t^{\alpha}(z_t L_t)^{1-\alpha}$ with labor augmenting exogenous technological progress, $z_{t+1}/z_t = \gamma_t$. Capital depreciates at rate d. Standard maximization problem of the firm yields the return on capital and real wage

$$r_t = \alpha K_t^{\alpha-1}(z_t L_t)^{1-\alpha} - d \quad \text{and} \quad w_t = (1-\alpha)K_t^{\alpha} z_t^{1-\alpha} L_t^{-\alpha}, \tag{16}$$

2.1 Equilibrium and model solving

As is standard in the literature, we employ the notion of a recursive competitive equilibrium. Recall that the state of an agent is fully characterized by $s_{j,t} = (a_{j,t}, \eta_{j,t}, f_{j,t}) \in \Omega$. We denote the probability measure describing the distribution of agents of age j in period t over the state space Ω as $\mathbb{P}_{j,t}$. Next we define equilibrium for our economy.

Definition 1 *A recursive competitive equilibrium is a sequence of value functions denoted by* $\{(V_{j,t}(s_{j,t}))_{j=1}^{J}\}_{t=1}^{\infty}$*, policy functions denoted by* $\{(c_{j,t}(s_{j,t}), l_{j,t}(s_{j,t}), a_{j+1,t+1}(s_{j,t}))_{j=1}^{J}\}_{t=1}^{\infty}$*, prices* $\{r_t, w_t\}_{t=1}^{\infty}$*, government policies* $\{\tau_{c,t}, \tau_{l,t}, \tau_{k,t}, \tau_t, \tau_{b,t}, \Upsilon_t, D_t\}_{t=1}^{\infty}$*, Lump Sum Redistribution Authority* $(\{tr_{j,i}(s_{j,t}))_{j=1}^{J}\}_{t=1}^{\infty}$ *, pension system characteristics* $\{\tau_t, subsidy_t, \rho\}_{t=1}^{\infty}$*, aggregate quantities* $\{L_t, A_t, K_t, C_t, Y_t\}_{t=1}^{\infty}$*, and a measure of households* $\mathbb{P}_{j,t}$ *such that:*

- ***consumer problem:*** *for each j and t the value function $V_{j,t}(s_{j,t})$ and the policy functions $(c_{j,t}(s_{j,t}), l_{j,t}(s_{j,t}), a_{j+1,t+1}(s_{j,t}), f_{j+1,t+1}(s_{j,t}))$ solve the Bellman equation* (11) *for given prices;*
- ***firm problem:*** *for each t, given prices (r_t, w_t), the aggregates (K_t, L_t, Y_t) solve the representative firm problem, satisfying equation* (16)*;*

- ***government sector:*** *the government budget and the PAYG pension system are balanced, i.e. equations* (13) *and* (14) *and, depending on the scenario, equations* (4) *or* (5) *are satisfied;*

- ***Lump Sum Redistribution Authority****: aggregated net present value of transfers and taxes across time and cohorts equals to zero, i.e. equations* (15) *is satisfied*

- ***markets clear***

$$
\begin{aligned}
\textit{labor market:} \quad L_t &= \sum_{j=1}^{\bar{J}} N_{j,t} \int_{\Omega} \omega_{j,t}(s_{j,t}) l_{j,t}(s_{j,t}) d\mathbb{P}_{j,t} && (17)\\
\textit{capital market:} \quad A_t &= \sum_{j=1}^{J} N_{j,t} \int_{\Omega} a_{j,t}(s_{j,t}) d\mathbb{P}_{j,t} && (18)\\
K_{t+1} &= A_t + D_t && (19)\\
\textit{goods market:} \quad C_t &= \sum_{j=1}^{J} N_{j,t} \int_{\Omega} c_{j,t}(s_{j,t}) d\mathbb{P}_{j,t} && (20)\\
Y_t &= C_t + K_{t+1} - (1-d)K_t + G_t; && (21)
\end{aligned}
$$

- ***probability measure:*** *for all* t *and for all* j*,* $\mathbb{P}_{j,t}$ *is consistent with the assumptions about productivity processes and policy functions.*

We solve the consumer problem with value functions iterations. In order to reduce the dimensionality of the state space we use the implicit tax approach (Butler 2002). We discretize the reduced state space $\hat{\Omega} = \hat{A} \times \hat{H}$ with $\hat{A} = \{a^1, ..., a^{n_A}\}$, and $\hat{H} = \{\eta^1, ..., \eta^{n_H}\}$, where $n_A = 750$ and $n_H = 3$. We interpolate policy and value functions with piece-wise linear functions (using recursive Powell's algorithm). For each discrete $\hat{s}_{j,t} \in \hat{\Omega}$ we find the optimal consumption and labor supply of the agent using Newton-Raphson method.

For given initial distribution $\hat{\mathbb{P}}_{1,t}$ at age $j = 1$ and time t and transition matrix $\Pi(\eta_{j,t}|\eta_{j-1,t-1})$ and the policy functions $\{a_{j+1,t+1}(\hat{s}_{j,t}), f_{j+1,t+1}(\hat{s}_{j,t}))_{j=1}^{J}\}_{t=1}^{\infty}$ we can compute the distribution in any successive age j and period t. It can be interpreted as a fraction of cohort of age j at time t residing at each state of the state space $\hat{\Omega}$. Once we compute distributions and policy functions for each state, we compute aggregate quantities of consumption, labor and savings. To this end we use Gaussian quadrature method.

Once the consumer problem is solved for a given set of prices and taxes, we apply the Gauss-Seidel algorithm to obtain the general equilibrium. Using the outcome of the consumer problem, the value of aggregate capital is updated. The procedure is repeated until the difference between the aggregate capital from subsequent iterations is negligible, i.e. l_1-norm of the difference between capital vector in subsequent iterations falls below 10^{-12}. Once the algorithm converges, utilities at $j = 1$ for all generations are computed.

2.2 Fiscal closures

We start our analysis by considering two fiscal closures: capital income tax and labor income tax progressivity. Later, we also consider other fiscal closures.

Capital income tax closure Tax on capital income adjusts immediately in each period to balance the pension system. It implies

$$\tau_{k,t} = \frac{G_t + subsidy_t + r_t D_t - \Upsilon_1 \sum_{j=1}^{J} N_{j,t} - \tau_{c,1} C_t - \tau_{l,1}(1-\tau^I) w_t L_t - \Delta D_t}{r_t A_t}. \qquad (22)$$

Both in the baseline and in the reform scenarios we compute the values of $\tau_{k,t}$ such that there is no change in the government debt, i.e. it is the same in the initial steady state, in the final steady state and on the transition path. Note that there are imbalances in the pension system, which exhibits time varying $subsidy_t$, that are covered by the government budget.

Such an immediate tax reaction of taxes to the social security reform implies that the costs of the reform are concentrated among the transition cohorts. To contain this effect, we also shift some of this cost to future generations by temporarily increasing the public debt. To avoid public debt explosion, we assume the following fiscal rule:

$$\tau_{k,t} = (1-\varrho)\tau_k^{final} + \varrho \tau_{k,t-1} + \varrho_D \left(D_t/Y_t - (D/Y)^{final} \right), \qquad (23)$$

where ϱ measures the speed of the adjustment in the capital tax rate, and ϱ_D the strength of reaction to deviation of government debt from its steady state values. The values of τ_k^{final} and $(D/Y)^{final}$ denote, in the final steady state, values of capital income tax and debt share in GDP, respectively. While the capital income tax in the final steady state may differ from the initial steady state, public debt to GDP ratio is identical.

To the best of our knowledge, only Keuschnigg et al. (2012) in a report for the World Bank consider capital income taxation, but as a measure accompanying the reform rather than a fiscal closure. Note that the reform, relative to the baseline scenario of maintaining a fiscally inviable DB PAYG pension system, yields ultimately lower overall taxation. Following the canonical result of Chamley (1986), Judd (1985), Atkeson et al. (1999)[6], taxing capital is inefficient. The lowering of the capital taxation implied by the pension system reform may further increase efficiency in the economy. However, in a life cycle framework with idiosyncratic income risk, the optimal capital taxes are not necessarily zero (Garriga 2001, Findeisen and Sachs 2017, Krueger and Ludwig 2018), but the optimal redistribution in the system may depend on the extent of agents, heterogeneity (in particular the heterogeneity of preferences, see Lockwood and Weinzierl 2015). The direct welfare effects of taxing capital are small (Golosov, Troshkin, Tsyvinski and Weinzierl 2013), but the efficiency boost in the economy may be sufficiently

[6] Recently Diamond and Spinnewijn (2011), Golosov, Troshkin, Tsyvinski and Weinzierl (2013), Straub and Werning (2014) revisit the topic, demonstrating that inter-temporal elasticity of substitution is quantitatively relevant.

large to outweigh the loss of insurance – it remains an empirical question to be addressed in our study.

Tax progressivity closure In this closure we introduce progressive labor income tax. There are four labor income thresholds implying five tax rates $\tau^i_{l,t}$ with $i \in \{0, 1, ..., 4\}$. Each income threshold is expressed as a multiple of average labor income after deduction of social security contribution, see Figure A1. Those thresholds are: $\{100\%, 125\%, 150\%, 175\%\}$ of average labor income. Income tax rates are given by $\tau^i_{l,t} = \tau^0_{l,t} * m^i$, where m is a tax multiplier. In the initial steady state all tax rates are equal, indicating $m = 1$. In the transition path (both baseline and reform), as well as in the final steady state, we arbitrarily, assume that $m = 1.15$. Therefore, the transitory increase in pension system costs of the pension systems are concentrated among high earners.

$$\tau^0_{l,t} = \frac{G_t + subsidy_t + r_t D_t - \Upsilon_1 \sum_{j=1}^{J} N_{j,t} - \tau_{c,1} C_t - \tau_{k,1} r_t A_t - \sum_{i=1}^{4} (w_t L_t)^i \tau^i_{l,t} - \Delta D_t}{w_t L_t} \tag{24}$$

$$\tau^i_{l,t} = m^i * \tau^0_{l,t}, \tag{25}$$

where $(w_t L_t)^i$ describe fraction of labor income taxed by $\tau^i_{l,t}$, which is given by

$$(w_t L_t)^i = w_t \sum_{j=1}^{\bar{J}} N_{j,t} \int_\Omega \max(\min(\omega_{j,t}(s_{j,t}) l_{j,t}(s_{j,t} - tr_1), tr_i - tr_{i-1}), 0) d\mathbb{P}_{j,t}.$$

Some earlier studies of pension system reform implement progressive income taxation (e.g. Nishiyama and Smetters 2007, McGrattan and Prescott 2017, Chen et al. 2016), but to the best of our knowledge none of them uses the changes in the progressivity as a fiscal closure. Progressive income taxation has long been demonstrated to provide insurance against idiosyncratic income shocks (Varian 1980, Golosov, Maziero and Menzio 2013, Heathcote et al. 2017). Our design implies that, in redistributing PAYG DB (baseline scenario), the scope of social insurance is further increased as the population continues to live longer and the fiscal costs of maintaining this system increase. Meanwhile, in the reform scenario, over the transition period, the costs are born predominantly by the high income earners, but as the implementation of the pension system reform progresses, the low earning individuals benefit from decreased labor income taxation. Hence, the insurance implicit in the PAYG DB system is partially replaced in the reform scenario with a more redistributive labor income taxation. Indeed, it appears that, in a life-cycle model with idiosyncratic income shocks, labor taxation should not be linear (Findeisen and Sachs 2017), but it remains to be determined if changing the scope of progressivity interacts with the incentives from the pension system reform.

Note, that the demographic change necessitates adjustments in the lump sum tax Υ in the baseline scenario. It is calibrated in the initial steady state to match the public debt and government deficit to the data. With an increasing number of agents in the economy, the *per* *capita* tax is bound to decrease. However, the decrease will be the same in the baseline and in the reform scenario, because the behavior of the population is identical.

2.3 Measuring welfare effects

The cohort-specific welfare effects of the reform are defined as a consumption equivalent, expressed as a percent of a lifetime consumption. Consumption equivalent for each agent is a percent of post-reform consumption that they would be willing to give up or receive in order to be indifferent between baseline and reform scenario. For a newborn with a logarithmic instantaneous utility function the consumption equivalent in percent of a lifetime consumption is given by:

$$M_{1,t} = 1 - \exp\left(\frac{V^B_{1,t} - V^R_{1,t}}{\sum_{s=0}^{J} \delta^s \frac{\pi_{1+s,t+s}}{\pi 1,t}}\right) \tag{26}$$

In this expression, $V^B_{1,t}$ and $V^R_{1,t}$ refer to lifetime utility of the newborn at period t, respectively, in base and reform scenario. In order to compute a consumption equivalent for agents alive in the first, pre-reform period, we have to take in to account their distribution $\mathbb{P}_{j,t}$ over state space Ω. Thus for cohort j years old at period 1 consumption equivalent is constructed by the following formula:

$$M_{j,1} = 1 - \exp\left(\frac{E(V^B_{j,1}) - E(V^R_{j,1})}{\sum_{s=0}^{J} \delta^s \frac{\pi_{j+s,1+s}}{\pi j,1}}\right) \tag{27}$$

The sign of the cohort-specific welfare effect of the reform $M_{j,i}$ is ambiguous, some cohorts gain from it and others lose. On the one hand, in the reform scenario currently working low productive cohorts face increasing taxes (due to higher deficit in the pension system) and lower pension benefits. Hence, it is more likely that $M_{j,1}$ for $j < \bar{J}$ is negative. On the other hand, the tax burden for the newborns is lower in the reform scenario than in the baseline. Thus, it is more likely that future cohorts gain, i.e. their consumption equivalent $M_{1,i}$ is positive. To calculate the overall welfare effect of the reform, we need to translate the aggregated cohort-specific welfare effect into the same for all cohorts consumption equivalent, expressed as a M percent of a lifetime consumption.

The total welfare effect of the reform M is given by:

$$M \sum_{t=1}^{\infty} \sum_{j=1}^{J} N_{j,t} \left(\sum_{s=1}^{J-j} \prod_{i=2}^{t-1+s} \frac{1}{r_i} \mathbf{E}(c_{j+s,t+s}) \right) =$$
$$= \underbrace{\sum_{j=1}^{J} N_{j,1} \left(M_{j,1} \sum_{s=1}^{J-j} \prod_{i=2}^{s} \frac{1}{r_i} \mathbf{E}(c_{j+s,1+s}) \right)}_{\text{discounted value for cohorts living at t=0}} + \underbrace{\sum_{t=2}^{\infty} N_{1,t} \left(M_{1,t} \sum_{s=1}^{J} \prod_{i=2}^{t-1+s} \frac{1}{r_i} \mathbf{E}(c_{s,t-1+s}) \right)}_{\text{discounted value for cohorts in future generations}} \tag{28}$$

M is the measure of the welfare effects of the reform in a Hicksian sense. $M > 0$ means that reform is welfare improving; after compensation of potential losses we still have some surplus generated by reform. This measure is analogous to Nishiyama and Smetters (2005, 2007).

In the spirit of Auerbach and Kotlikoff (1987), Nishiyama and Smetters (2005, 2007), LSRA compensates households who would otherwise lose from reform and spreads equally the remaining welfare gains. The lump-sum transfers made by the LSRA are given by:

$$tr_{j,t}(s_{j,t}) = (M - M_{j,t})c_{j,t}(s_{j,t}) \tag{29}$$

Once LSRA transfers are computed, they are allocated to agents and new equilibrium is recalculated. This procedure is repeated iteratively, until a fixed point solution is reached, i.e. transfers do not change between iterations (Nishiyama and Smetters 2005). This step allows to take into account the reaction of agents to redistributive transfers.

3 Calibration and baseline

The model is calibrated to match features of the US economy. The model period corresponds to five years. Using microeconomic evidence and the general characteristics of the US economy we established reference values for preferences, life-cycle productivity patterns, taxes, technology growth rates, etc. Given these, the discount factor δ was set to match the initial steady state interest rate of 4%. Depreciation rate d is set so that the aggregate investment rate matched the one observed in the data, i.e. app. 25%. The calibration of the model parameters is summarized in Table A2.

Demographics. Demography is based on the projection by The United Nations. As input data we use the number of 20-year-olds born at each period in time and mortality rates. Projection period is 50 years for population and 90 years for mortality rates. After periods covered by projection we assume that mortality stabilizes and that annual population growth rate converges to 1.002 in the final steady state, see Figure A2.

Productivity growth (γ_t). The model specifies labor augmenting growth of technological progress $\gamma_{t+1} = z_{t+1}/z_t$. The debate about the future of the US growth is ongoing (e.g. Fernald and Jones 2014, Gordon 2014). We assume a steady technological progress at the current rate of 2% per annum, constant over the whole transition path. Note that although the technological progress is the same in baseline and reform scenarios, higher values of γ are beneficial for the PAYG systems. With a stable technological progress, the main secular driver of the changes in the interest rate is demographics. As a robustness check, we introduce specifications with a gradually declining technological progress. Our conclusions are not dependent upon this assumption (see Table A9 in the Appendix).

Idiosyncratic productivity shock (η). The idiosyncratic component is specified as a first-order autoregressive process with autoregression $\bar{\varrho}_\eta = 0.95$ and variance $\bar{\sigma}_\eta = 0.0375$ which are based on estimates from Krueger and Ludwig (2013). In our model each period corresponds to 5 years. Hence we need to recalculate input variables according $\varrho_\eta = \bar{\varrho_\eta}^5$ and $\sigma_\eta = \bar{\sigma}_\eta \frac{1-\bar{\varrho_\eta}^5}{1-\bar{\varrho}_\eta}$.

Preferences. We calibrate the preference for leisure parameter ϕ to match the observed share of hours worked in the economy, which is 33% on the average. The discount factor δ was set at 1.006^5 to match the interest rate of 4%. Since agents face mortality risk, the effective discount rate is below 1.

Pension system parameters We set the replacement rate (ρ) to match the 5.2% ratio of pensions to GDP. The effective rate of contribution τ was set such that the pension system deficit in the original DB steady state is equal to 0. Retirement age eligibility in the US occurs at 66, which is equivalent to $\bar{J} = 9$.

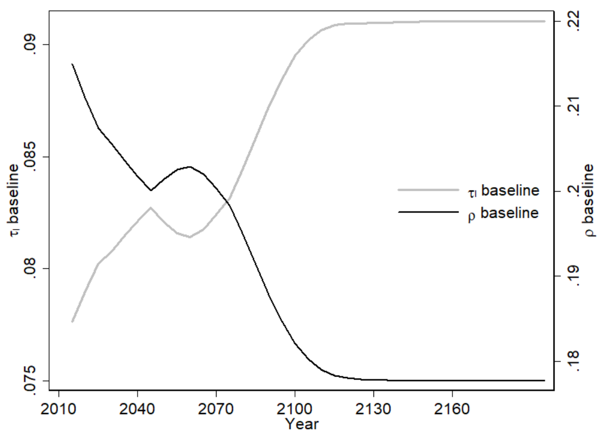
Taxes. The capital income tax was set to 13%, to match 3.6% share of the capital income tax revenues in GDP. The marginal tax rates on labor and consumption were set to 15% and 6.5%. It matches the rate of labor income tax revenues in GDP (9.2%) and that of consumption tax (3.8%). The calibration of tax rates is based on the OECD data, see Table A3. We calibrate the lump sum tax Υ_t in the initial steady state to match the debt/GDP ratio of 1% and keep it unchanged in per capita terms throughout the whole transition path in both baseline and reform scenarios.

3.1 Baseline scenario

With changes in demography, maintaining *status quo* of PAYG DB pension system requires adjustments in the pension system. Beyond the horizon of our analysis, the imbalance in the pension system increases to roughly 1.5% of GDP. To give context to this number, we show the scale of the adjustment in the pension system parameters necessary to prevent these imbalances in Figure 1. It reports the changes in the pension system parameters – the contribution rate or the pension benefits – that would be required for fiscal neutrality of the pension system (for simplicity, in the initial steady state we assume balanced pension system). Indeed, the replacement rate would need to go down by as much as 17% (from roughly 21.5% to below 17.8%). These results are consistent with Fehr (2000), Braun and Joines (2015). Note, that these adjustments occur despite relatively favorable demographics: the population growth rate is positive throughout the whole period. We also took a conservative assumption that technological progress will continue at a stable rate. Hence, the only source of these adjustments in the baseline scenario of our model is longevity.

The changes in the population structure influence aggregate labor supply and aggregate savings. This affects factor prices for labor and capital. As labor will become scarcer, relative to capital, real wages rise and real returns to capital decline. Pension system privatization amplifies this pattern, (see also Krueger and Ludwig 2007, Attanasio et al. 2007). Nevertheless,

Figure 1: Baseline scenario – the effects of demographics



Note: Figure depicts adjustment needed in pension system to maintain fiscal neutrality (defined as $\forall_t subsidy_t = 0$). The policy option denoted as τ adjusts the contribution rate to maintain pension system balanced. The policy option denoted as ρ adjusts the pensions to maintain pension system balance.

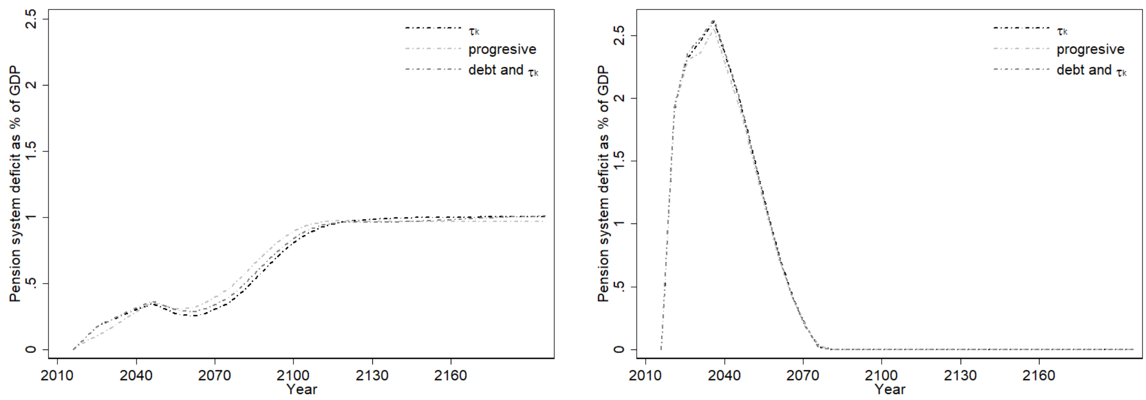
due to falling fertility, the payroll growth rate is lower that the interest rate in long run. Hence, pension reform implies higher returns from obligatory pension savings than from private voluntary savings.

4 Results

The reform affects the government budget in two important ways. First, a fraction of the contributions is diverted from the pay-as-you-go pillar to the funded pillar, which further reduces the revenues of the public pension pillar. Second, the DC PAYG pillar, contrary to the DB PAYG system, is constructed in such a way that once the transition period is over it is balanced so there is no need to subsidize it. Hence, the reform necessitates relatively high transition cost, but brings fiscal relief in the long run. In our simulations in the first period of the reform, the social insurance fund deficit grows to roughly 2% of GDP (from a calibration of 0% in the initial steady state), but in approximately 2070 it is brought back to 0% (Figure 2b). By contrast, longevity raises deficit in the unreformed pension system to the 1% of GDP in the long run (Figure 2a).

From the point of view of the agents, the reform brings about two important changes. First, it links benefits to the pension contributions (both in the funded and in the PAYG pillar). Thus, it reduces the insurance against the income risk provided by the Beveridgean pension system on the one hand and reduces the labor wedge associated with the pension system contributions on the other hand. Second, since the reform necessitates fiscal adjustment, the tax burden increases during the transition period to decline later on. Since taxes are distortionary and redistributive, these fiscal changes by themselves have impact both on the degree of the efficiency gain and on

Figure 2: Pension system deficit as % of GDP



(a) baseline

(b) reform

the extent of insurance loss due to the reform. Earlier literature suggests that the insurance motive is an important driver of the welfare effects of the pension system reform – important enough to change the evaluation of the reform (e.g. Nishiyama and Smetters 2007).[7]

Table 1 demonstrates that it need not always be the case. We present the welfare effects of the reform and the political support for the reform in an economy with uninsurable idiosyncratic income shocks. The political support is measured as a fraction of population living at the time of the reform who would benefit from the reform and thus should be expected to favor it over *status quo*. We first analyze the two fiscal closures which are new in the literature: capital income taxation (with and without smoothing via public debt), and labor tax progression. The welfare effects are presented both for the final steady state and aggregate (i.e. for the whole transition path). Following the diagonal, we report the results from scenarios, where baseline and reform path employ the same fiscal closure. Outside the diagonal we report the results from the scenarios where baseline followed a different fiscal closure than the reform, i.e. the combined effects of the reform and the fiscal closure. Four main findings are apparent from Table 1. First, the same reform may be both welfare improving and welfare deteriorating depending on the fiscal closure. Second, with capital income tax closure, our reform is welfare improving independently of what the closure is in the baseline. Third, not all welfare improving reforms gain political support. In fact, there seems to be little relation between the welfare effect of the reform and political support for it. One regularity that stands out (and it can be also observed on a larger set of closures that we show later) is that using debt closures in the reform scenarios improves political support with little change in welfare effect. In the debt closure, the increase in taxes necessitated by the reform is postponed, which allows some of the burden of the reform transition costs to be shifted onto future generations. Finally, as is often the case in this literature, the reform improves welfare in the long run, independently of the

[7]To understand better the impact of the reform, we decompose it later into the efficiency gain and the insurance loss effects.

fiscal closure.

Table 1: Welfare effects of the pension system reform

Fiscal closure		Baseline τ_k	Baseline $debt + \tau_k$	Baseline $progression$
		Welfare effects – final steady state (%)		
Reform	τ_k	0.85	0.85	1.25
	$debt + \tau_k$	0.85	0.85	1.25
	progression	-0.11	-0.11	0.32
		Welfare effects – aggregate (%)		
Reform	τ_k	0.83	0.83	1.23
	$debt + \tau_k$	0.82	0.82	1.23
	progression	-0.32	-0.32	0.12
		Political majority (%)		
Reform	τ_k	35	43	58
	$debt + \tau_k$	58	66	82
	progression	35	43	43

Note: Results report final steady state level difference and aggregate welfare effects for all cohorts in % of lifetime consumption, following equation (28). Political majority computed as a fraction of cohorts living in the first year (steady state) benefiting from the reform, gray area denotes closures that yield the aggregate welfare gains. Closures τ_k stand for immediate adjustment of capital income tax, compare with equations (22). Tax progressivity closure is indicated as $progression$, see equations (24) - (25). Closures $debt+$ τ_k permit the use of public debt to temporarily fund the costs of the pension system reform, with fiscal rule described in equation (23).

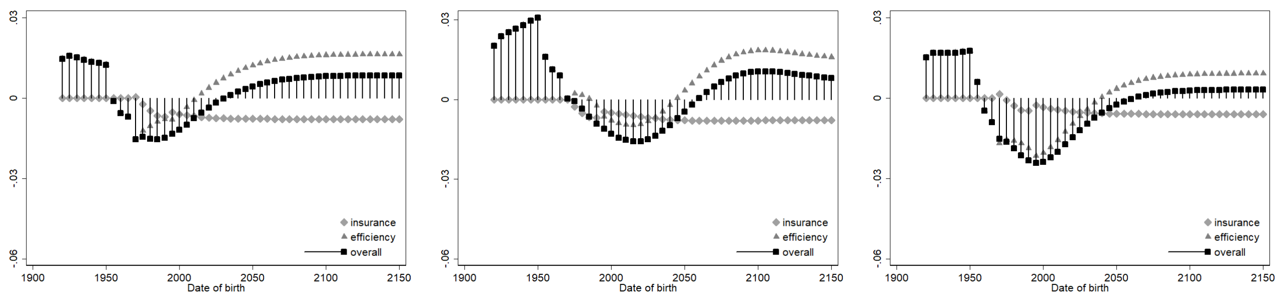
In order to better provide the intuition behind these results, in Figure 3 we decompose the overall impact of the pension reform into the welfare effect of the insurance change and of the efficiency change for the subsequent cohorts. The decomposition is obtained through a partial equilibrium exercise. In order to obtain the welfare effect of the insurance change, we keep prices and labor choices from the reform scenario but replace individual pensions with average pensions computed for each cohort. Given income, consumers are allowed to choose only the new consumption path. Then, we recalculate welfare as in equation (28). In this exercise, labor supply is exogenous (we impose the same labor supply as chosen endogenously in the general equilibrium scenario). By consequence, the provision of the insurance in the pension system – the replacing of the individual pension benefits with cohort averages - does not distort the labor choice. This way we limit the scope of inefficiency insurance could generate. Instead, we isolate the welfare effect of the change in the insurance provided implicitly in the pension system. We subtract this partial equilibrium measure of welfare from the total welfare effect of the reform to obtain the welfare measure of the efficiency gain as a residual.

This decomposition reveals that indeed the welfare effect of the loss of insurance due to the reform is negative.[8] However, the strength of this effect depends on the fiscal closure. In the case of capital tax closure, in the final steady state, the welfare effect of the loss of insurance equals -0.78% of lifetime consumption, while in the case of progressive taxation only -0.60%. This difference stems from the fact that progressive taxes provide some insurance

[8]Note that this welfare loss is likely to be an upper bound, because we assume full insurance in baseline.

against income risk while capital income taxes do not. Moreover, the degree of the efficiency gain resulting from the reform varies with closure as well. Since lowering capital income taxes is more beneficial than lowering labor taxes, the welfare effect of the efficiency gain in the new steady state in case of the capital income tax closure of 1.60%, is larger than for the progressive labor tax closure of 0.91%. Indeed, the tax closure may reinforce or attenuate the effects of the reform both in terms of efficiency and in terms of insurance against income risk. Whether the total welfare effect of the reform is positive or negative largely depends on the size of the inefficiency introduced in the transition phase, when the taxation needs to increase in order to finance the gap in the pension system. That transitory period of increased taxation yields a large welfare loss across all scenarios. Here we observe a pattern similar to the one in the final steady state. First, if progressive taxes are used to close the fiscal side of the economy, the loss of insurance is smaller. But, it seems that an overall hike in labor taxation (even if redistributive) imposes a larger distortion and this is why the total welfare effects for this closure are smaller than in the case of capital income taxation.

Figure 3: Consumption equivalent (% of permanent consumption in reform scenario)



(a) τ_k (b) debt + τ_k (c) progression

Note: We report the consumption equivalents from scenarios where the same fiscal closure is assumed for the baseline and reform scenario (i.e. the result reported on the diagonal of Table 1).

Notably, during the transition period, the efficiency effects are negative even though the distortion stemming from the pension system is immediately removed by introducing the direct link between pension benefits and contributions. Recall that prior to the reform, agents viewed the social security contributions as a tax, whereas they become fully internalized as a future stream of income once the reform is implemented. This considerable decline in labor taxation is offset by an increase in taxation (progressive labor tax or capital income tax) to finance the gap in the pension system induced by establishing the capital pillar.

The cohort distribution of the welfare effects reveals how using the debt closure in the reform scenario can help assure political support for the reform. The comparison of the pure capital income tax closure with the case when tax adjustment is smoothed by public debt reveals that, by allowing the public debt increase during the transition period, the necessary increase in taxation may be postponed. Spreading the burden of the transition cost across many generations makes the cost born by each generation smaller. The reduction in the transition cost sways the political support of additional cohorts alive at the moment of the reform in favor of the reform. Our results also hint that if progressive labor taxation was combined with the tax smoothing through the use of public debt, political support could also be achieved.

Note that the extent of progression is relatively modest and yet it is providing a substitute for the insurance implicit in the Beveridgean pension systems. In Figure A4 we report how the progression in general affects the consumption inequality in baseline and reform. In fact, inequality is lower with the pension system reform even without tax progression, due to the labor supply response among those who had relatively lower labor supply prior to the reform. This equalization effect of increased labor supply, however, is not the only force at work. Even in the baseline scenario, when the pension system provides insurance against idiosyncratic income shocks *after retirement*, progressive taxation contributes to lower consumption inequality by also reducing inequality for individuals prior to the retirement age. With the introduction of the reform, greater progression allows further reduction in inequality of consumption. Note that this is achieved despite relatively little redistribution in the tax system. The Kakwani index, which informs about the extent of redistribution via labor taxation, falls short of 6%, see Figure A5 (being higher in the reform than in the baseline scenario). Typical reforms to tax systems or health systems yield changes in the Kakwani index of 1-2 percentage points (Yu et al. 2008). Meanwhile, the scope of progression needed to finance the pension reform in our setting is about 0.4 of a percentage point.

These results confirm that systemic pension reform and the the methods for financing it exhibit a complementarity. The studied fiscal closures amplify the efficiency gain or substitute (even if only partially) for the insurance loss due to the fact that the new pension system no longer redistributes between agents within cohorts. We showed that such complementary fiscal policies may render pension system reform welfare improving and politically favored despite stochastic setting. The difference between our results and the findings of the earlier literature rests until now upon different fiscal closures adopted in our approach. Next, we move on to consolidating the welfare implications of reforming the pension system with a variety of fiscal instruments considered in isolation by the earlier literature.

4.1 Extension – the other fiscal closures

We consider a wide array of fiscal closures discussed in the earlier literature.[9] The first set of closures is fiscally neutral and necessitates adjustments only within the pension system. We analyze a change in pension benefits and a change in the contribution rate such that the pension system is balanced ($\forall t \; subsidy_t = 0$). The second set of fiscal closures leaves the parameters of the pension system intact, but adjusts taxes and public debt to accommodate for the changing demography in the baseline scenario and the demography coupled with the pension system reform in the reform scenario. We consider labor tax and consumption tax, with and without

[9] Table A1 summarizes the use of these closures in the earlier literature.

smoothing via public debt. Appendix B presents them in detail.

In total, this yields six fiscal closures (two within pension system and thus fiscally neutral and four allowing fiscal adjustments to balance the pension system).[10] Indeed, if fiscal closure was neutral to the evaluation of the reform, one should expect both aggregate welfare and between cohort distribution of welfare effects to be similar. This is not the case. For each of the analyzed fiscal closures, we display the final steady state welfare, aggregate welfare and political support in Table 2 as well as the cohort distribution of the consumption equivalents in Figure 4. Our comparison reveals stark differences between fiscal closures for the same pension reform, as inferred from the numbers along the diagonal, which isolate the effects of the reform conditional on a fiscal closure. The numbers for the aggregate welfare range from positive to negative, suggesting that fiscal closure is an important driver of the overall welfare change.

Table 2: Welfare effects of the pension system reform

	Fiscal closure	Baseline τ	pensions (τ_b)	τ_c	τ_l	$debt\tau_c$	$debt\tau_l$
		Welfare effects – final steady state					
Reform	τ	0.36	0.27	0.21	0.21	0.21	0.21
	pensions (τ_b)	0.35	0.26	0.20	0.20	0.20	0.20
	τ_c	0.32	0.25	0.11	0.11	0.11	0.11
	τ_l	0.20	0.14	-0.07	-0.07	-0.07	-0.06
	$debt\tau_c$	0.31	0.24	0.10	0.10	0.10	0.10
	$debt\tau_l$	0.20	0.14	-0.06	-0.06	-0.06	-0.06
		Welfare effects – aggregate					
Reform	τ	0.08	0.08	-0.05	-0.04	-0.05	-0.04
	pensions (τ_b)	0.07	0.06	-0.07	-0.06	-0.07	-0.06
	τ_c	0.08	0.08	-0.09	-0.09	-0.10	-0.08
	τ_l	-0.03	-0.05	-0.25	-0.25	-0.25	-0.25
	$debt\tau_c$	0.06	0.06	-0.12	-0.11	-0.12	-0.11
	$debt\tau_l$	-0.04	-0.05	-0.25	-0.25	-0.25	-0.25
		Political majority (in %)					
Reform	τ	58	58	58	58	58	58
	pensions (τ_b)	0	0	0	0	0	0
	τ_c	35	43	35	43	35	43
	τ_l	43	50	43	43	43	43
	$debt\tau_c$	43	50	43	50	43	50
	$debt\tau_l$	58	58	43	58	50	58

Note: Results report final steady state level difference and aggregate welfare effects for all cohorts in % of lifetime consumption, equation (28). Political support computed as a fraction of cohorts living in the first year (steady state) benefiting from the reform, gray area denotes closures that yield the aggregate welfare gains. Closure τ denotes the situation in which contribution rate is adjusting to make the pension system fiscally neutral, as in equation (31). Closure τ_b refers to situation in which pension benefits are reduced to ensure pension system balance, see equation (31). Closures τ_c and τ_l stand for immediate adjustment of consumption and labor and capital income tax respectively, compare with equations (32) and (33). Closures *debt* τ_c and *debt* τ_l permit the use of public debt to temporarily fund the costs of the pension system reform, with fiscal rule described in equation (23).

[10] Given that, the immediate cause of the pension system reform is longevity, from the fiscal perspective, the question of the labor supply becomes dependant on another factor: the minimum eligibility retirement age. In a setup where one period is equivalent to five years, raising the retirement age is understandably questionable.

Our results replicate the findings of the earlier literature (e.g. Davidoff et al. 2005, Nishiyama and Smetters 2007, Fehr et al. 2008, Harenberg and Ludwig 2016), but we also show that they are far from universal. Indeed, positive welfare effects are possible even in the stochastic setting: for many starting points (fiscal closure in the baseline scenario), there exists a fiscal closure for the reform scenario which yields welfare gains from the reform. Some of the welfare improving scenarios even stand to gain political support. Notably, there are also closures which gain sufficient political support to be chosen democratically, but which deliver welfare loss in aggregate terms. Figure 4 portrays the distribution of the welfare effects across cohorts measured at the age of $j = 1$ for each subsequent cohort, computed as a difference between the expected utilities from baseline and reform scenarios.[11] Figure 4 strongly corroborates the intuition that different policy options in baseline and reform scenarios actually result in different between-cohort redistribution of welfare. For example, closures with contribution rates are neutral to initial retirees and almost neutral to cohorts close to retirement. By contrast, adjustments in consumption tax, even if smoothed by the public debt – imply that the welfare of these cohorts increases less or actually decreases due to the introduction of partially funded DC.

Fiscally neutral closures – reduction in pension benefits and increase in pension contributions – yield positive welfare effects, but only adjustment in the pension contributions is politically favored. In our setup, changing contributions is effectively reducing labor distortion, because the "additional" contributions, used to finance the pension system balance, are not accrued to future pension benefits. However, pension system reform itself provides such strong incentives for upward adjustment in labor supply that the tax base increases by more than necessary to finance the costs of the pension system reform. In the reform scenario, the link between labor supply and future benefits is clear for all agents. As a consequence, labor supply increases significantly, see the top panel of Table A4 in the Appendix. The increase ranges between 7% and 10% relative to the baseline scenario, depending on the distortion introduced by the fiscal adjustment (notably, in the baseline scenario).[12]

Indeed, in the baseline scenario, the adjustment in pension system parameters necessitated by fiscal neutrality is substantial, recall Figure 1 with a substantial increase in the contributions rate. In the reform scenario, the contribution rate declines by as much as 4 p.p. relative to the initial steady state and 5 p.p. relative to the baseline, see Figure A6. Hence, the contribution rate declines relative to the baseline, almost instantaneously, further increasing the incentives to work. Unlike labor or consumption taxes, increases in the contribution rates are irrelevant to the initially old, which makes up for a larger share of gaining cohorts. Furthermore, this fiscal adjustment is favored by the cohorts who were already retirees in the initial steady state (see Figure 4a), as opposed to the reduction in pension benefits (see Figure 4d). Moreover, while in

[11] For the cohorts living at the time of reform ($j - t > 1$) the difference in utilities is computed as averaged for idiosyncratic income shocks within cohort, i.e. the gains from the reform are measured as identical for each individual within these few initially old cohorts.

[12] Note, that this economy experiences a population growth, which implies that the labor supply increases irrespectively of the reform.

the baseline scenario the replacement rate has to decline to balance the pension system, in the reform scenario the implied replacement rate (computed as the first pension to the last wage) may increase, due to the increased labor supply, which stems from the stronger incentives in the defined contribution setup.

The above results are novel relative to the literature. In terms of magnitude, the overall effects we find are similar for the final steady states when compared to studies which utilize an OLG model with individual uncertainty. For example Fehr and Kindermann (2010) find long run welfare gains of roughly 0.2% for Germany, whereas Kitao (2014) finds 0.7% for the case of the US although his pension system has a somewhat different design (benefits increase with earned incomes, but do not decline with longevity).[13]

Our results are also partly counter-intuitive. Typically, one would expect consumption taxes to yield welfare gains in the reform scenario. Consumption taxes, in contrast to labor taxes, are neutral intra-temporally: gross consumption and labor supply are uninfluenced. However inter-temporal choice is affected. The link between labor supply and pension benefits, implicit in the defined contribution pension system, appears to cause a very strong reaction by the households. Indeed, taxes decline substantially and they may decline almost immediately in the closures which combine taxes and public debt, see Figure A3. While working more is not welcome in principle, immediate reduction in the implicit labor taxation due to the reform is sufficient to cause a substantial increase in taxable labor supply, thus, to an extent, financing the introduction of the funded pillar.[14]

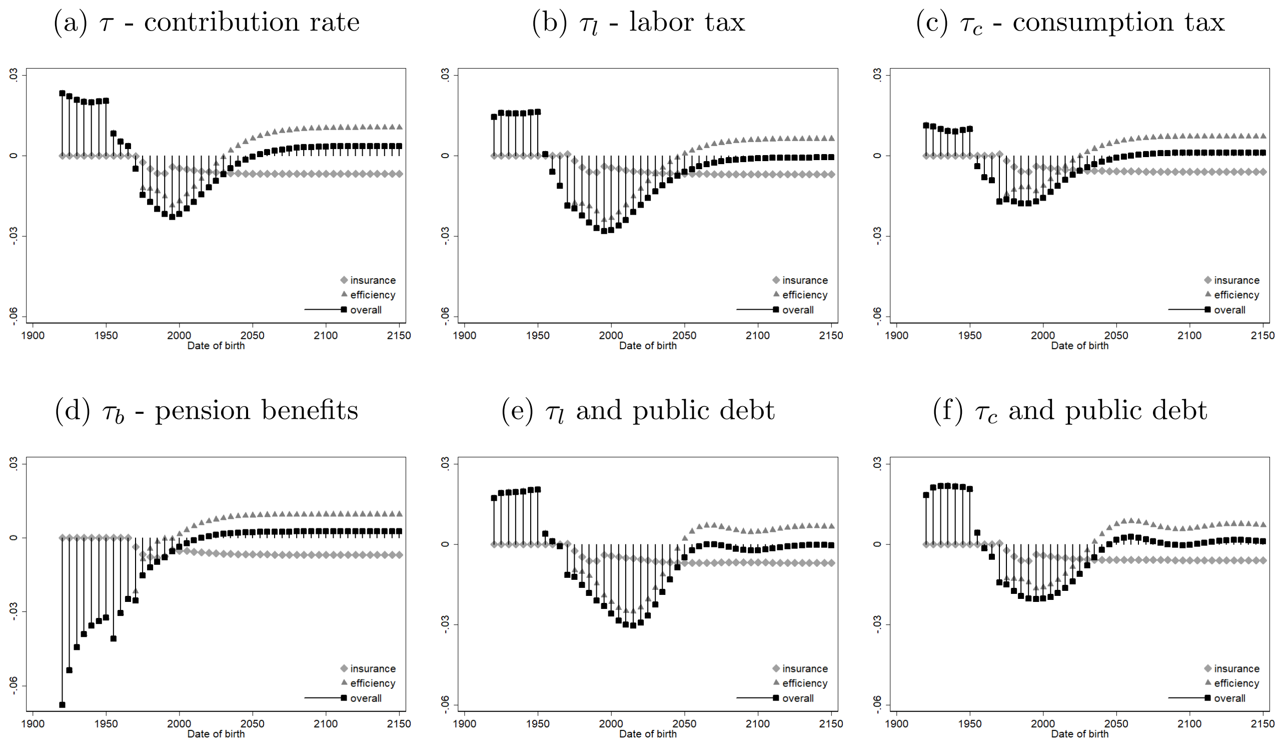
We complement the aggregate welfare analysis with the overview across cohorts and its natural extension: analysis of the political support for introducing the reform with alternative

[13]The setup of Imrohoroglu et al. (2003) is different in a sense that agents in their model see no link between labor supply and future pensions. Moreover, they use pension contributions as a fiscal closure, but in their setup it is equivalent to an increase in labor taxation. In fact, our results provide an intuition for why Imrohoroglu et al. (2003) find large, negative effects in a model with uncertainty: labor taxation as fiscal closure reinforces the negative welfare effects of reducing the insurance motive. However, the negative welfare effects in this study are not as much due to the reform itself, as due to the model setup combined with fiscal closure. Unlike our setup, the increase in labor supply in the setup of Imrohoroglu et al. (2003) is insufficient to finance the reform, which triggers upward adjustment in taxes. We are more closely related to Imrohoroglu et al. (2003) than to **?**Nishiyama and Smetters (2007) because the latter analyze a different reform. However, the comparison of the mechanics is similar with reference to both studies.

[14]For the sake of comparison with earlier literature, we also provide results of the same reform in a deterministic setting. These results are reported in Table A8. The results reported concern an economy with the same parameters, hence we cannot match the same moments in economic variables. Hence, we also provide results with a deterministic economy recalibrated to match the same moments in economic variables (details on recalibration in Table A6). We find many similarities between the stochastic and the deterministic model, though admittedly the welfare effects are much larger in the deterministic model, hinting at a large role for the insurance motive *per se*. Notwithstanding, many conclusions are the same: it is never politically favored to adjust pensions, although it brings the largest aggregate welfare gain. By contrast, closures with public debt often get political support despite being relatively less beneficial from the welfare perspective. Unlike the stochastic case, though, public debt is not the only way to convince the living cohorts to adopt the reform – in fact there are many more options for garnering political support. The reason is revealed by Figure A7, which compares the cohort patterns of the welfare effects for both the stochastic and the deterministic models (with analogous calibration and recalibrated). Indeed, cohort patterns are quite similar – the main difference is the level of consumption equivalent, which is much higher in the deterministic scenarios. Notably, recalibration is of minor importance.

fiscal arrangements. While most of the non-neutral closures are detrimental to welfare in aggregate terms, many of them yield sufficient political support. For example, often there is sufficient share of living cohorts benefiting from the reform that solutions with public debt and taxation are favored politically despite bringing a welfare loss. This is especially true for consumption taxation, where in every scenario political support is warranted despite only three adjustment scenarios leading to welfare improvement. This result comes from the fact that generations living at the time of reform only partially experience change in the pension system and nearly all of them benefit from the accompanying fiscal adjustments, see Figure 4. The exception, of course, is the reduction in pension benefits – despite providing sound welfare gains in the long run and overall, it is never politically favored at the moment of the reform.

Figure 4: Consumption equivalent (% of permanent consumption in reform scenario)



Note: We report the consumption equivalents from scenarios where the same fiscal closure is assumed for the baseline and reform scenario (i.e. the result reported on the diagonal of Table 1).

5 Discussion and conclusions

Pension system reform from a defined benefit pay-as-you-go system to a defined contribution system allows for better alignment in the labor supply incentives between macro and micro-levels, reducing the scope for labor supply distortions. However, individual productivity risk becomes more afflicting. This trade off has been at the core of many earlier studies (e.g.

Heer 2015). In the traditional view, the welfare loss from no longer insurable income shocks dominates the overall efficiency gain in the economy. The earlier literature, however, considered fiscal closures a necessary yet secondary issue.

Our contribution is to show that pension reform should be analyzed in conjunction with the fiscal policy options, because the fiscal closure may to a large extent reverse or reinforce the effects of the reform. Our findings reveal that the fiscal closure itself can change the evaluation of the reform – from negative to positive. The paramount role of the fiscal closure extends to the long run, i.e. they are not only affecting the inter-cohort redistribution, but also the overall efficiency. Naturally, the fiscal closure also matters for the provision of political support.

The policy implications of this study are quite optimistic. First, despite reducing the insurance motive, reforming the pension system from defined benefit to defined contribution may improve welfare and be politically favored at the same time, at least for some fiscal adjustments accompanying the reform. Moreover, even in the stochastic environment, the efficiency gain is sufficient to finance the formation of the capital pillar. Third, the benefits stem, to a large extent, from strengthening the link between the contributions and the pension benefits. This implies that, for a reform to deliver expected outcomes, some effort may be necessary to educate the citizens and thus encourage adequate response to implicitly changing incentives. Indeed, the labor supply reaction suggested by the overlapping generations model calibrated to the case US economy is large.

Given that our results depend largely on the labor supply response by households to better aligned incentives, one can ask if the size of the reaction is plausible. Admittedly, reform immediately reduces labor taxation by virtually the entire social security contribution: agents used to treat the contributions as a tax and suddenly treat them as postponed stream of revenue. Given the magnitude of the contribution rate, the sizable increase in labor supply – roughly 6.5% to 9% – may be justifiable in a macroeconomic model. A large selection of studies reviewed empirical evidence from numerous labor taxation reforms, yielding the plausible Hicksian labor supply elasticities of roughly 0.3-0.4 for the intensive margin and roughly 0.1 for the extensive margin (e.g. Keane and Rogerson 2012, Chetty 2012). Such estimates would be consistent with our outcomes. Admittedly, most of these studies concern labor taxation *per se*, not long-term optimization between contributions, benefits and labor supply, as such studies are rare. A large response here is conditional on workers internalizing the entire adjustment in their decision-making process. Concerning this point, empirical literature is not as optimistic. For example, using evidence from Denmark, Chetty et al. (2011) show that people tend to respond to nominal taxation (and their changes) and are relatively inattentive to real taxation changes, even if the latter are relatively large. The reform we model would fit the latter type.

Summarizing, our study has challenged the consensus in the literature concerning the relative size of the efficiency gain and insurance motive in determining the effects of pension reform privatization. The decomposition through a partial equilibrium exercise reveals that the insurance motive is indeed sizable, but need not determine the welfare effects of the pension system reform if the original effects are amplified by an adequate fiscal closure. We also show that such complementary policies may gain sufficient political support even in a stochastic environment. Financing the transitory cost of forming the capital pillar with public debt allows the costs of the reform to be spread across many generations, introducing a tool for an automatic redistribution between cohorts. However, the political preferences and the welfare effects are not always aligned. Many policy variants result in policy support for the pension system privatization, despite being detrimental to welfare, whereas some policies improving welfare may not obtain sufficient political support.

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A Literature overview

Table A1: Modeling options taken in the earlier literature

Paper	Problem	Solution	Soc. sec. parameters	Introducing	Fiscal closures	Implicit tax	Idiosyncratic shocks
Belan and Pestieau (1999)	aging	p and s	τ_I	FF	debt	NO	NO
Fehr (2000)	aging	p	$\tau_I, \bar{J}, \tau_b$		τ_c	YES	NO
Imrohoroglu et al. (2003)	aging	p and s	τ_I	DC		NO	YES
Lindbeck and Persson (2003)	aging	s		DC, DC+FF	debt	NO	NO
?	risk	PAYG DB	τ_I			NO	NO
Keuschnigg et al. (2012)	aging	p	$\bar{J}, \tau_I, \tau_b$		τ_c, τ_l, τ_k	NO	NO
Sanchez-Marcos and Sanchez-Martin (2006)	dem. uncert.	PAYG DB	τ_l			NO	YES
Verbič et al. (2006)	aging	p	τ_I		τ_c, τ_l	NO	NO
Aglietta et al. (2007)	aging	p	$\bar{J}, \tau_I, \tau_b$			NO	NO
Nishiyama and Smetters (2007)	aging	s		PRIV	τ_c	NO	YES
Verbič (2007)	aging	p	τ_l		τ_c	NO	YES
Andolfatto and Gervais (2008)	aging	p	τ_I			NO	NO
Bassi (2008)	aging	p	$\bar{J}, \tau_I$			NO	NO
Heer and Irmen (2014)	aging	p	$\tau_b, \tau_I, \bar{J}$	M	Υ	NO	NO
Díaz-Giménez and Díaz-Saavedra (2009)	aging	p	$\tau_I, \bar{J}$		τ_c	YES	NO
Fehr and Kindermann (2010)	aging	s		FF	τ_c	YES	YES
Kuhle (2010)	aging	s		PRIV	debt	NO	NO
Kumru and Piggott (2010)	aging	s		M, PRIV	τ_c	NO	YES
Kumru and Thanopoulos (2011)	aging	s		FF, PRIV	τ_I	NO	YES
De la Croix et al. (2012)	aging	s	$\bar{J}$	FF	τ_c	NO	NO
Wright et al. (2012)	aging	p	τ_I		DEBT	NO	NO
Cipriani and Makris (2012)	aging	p and s	τ_I	FF		NO	NO
Bruce and Turnovsky (2013)	aging	p	τ_I		τ_I	NO	NO
Börsch-Supan et al. (2014)	aging	p or s	$\tau_b, \tau_I, \bar{J}$			YES	NO
Kitao (2014)	aging	p or s	$\tau_b, \tau_I, \bar{J}$	M	τ_I	NO	YES
Song et al. (2015)	aging	s		FF	debt	NO	NO
Kitao (2015)	aging	s		FF	τ_c	NO	NO
Chen et al. (2016)	aging, risk	p or s	τ_b, τ_I	COL		NO	NO
Vogel et al. (2017)	aging	p	$\tau_I, \tau_b, \bar{J}$			NO	NO

Notes: p denotes parametric reform, s denotes systemic reform, NPS denotes fiscally neutral pension system; FF for introducing fully funded accounts; DEBT denotes debt repayment; PRIV denotes removing pension system; M denotes means-tested program, PAYG DB denotes introducing PAYG DB pension system; COL denotes collective pension fund, risks can be shared over many cohorts of participants. In addition, using various fiscal closures, Bouzahzah et al. (2002), Fehr et al. (2008), Boersch-Supan and Ludwig (2010), Roberts (2013), McGrattan and Prescott (2017) model removing of the pension system at all.

B Additional fiscal closures

Fiscally neutral closures Recall that with $subsidy_t = 0$, equation (4) becomes:

$$\sum_{j=\bar{J}_t}^{J} N_{j,t}\rho_t \cdot w_{avg,t-j+\bar{J}} \prod_{i=1}^{j-\bar{J}} (1 + r^I_{t-j+\bar{J}+i}) \quad = \quad \tau_t w_t L_t$$

$$\rho_t = \frac{\tau_1 w_t L_t}{\sum_{j=\bar{J}_t}^{J} N_{j,t} \cdot w_{avg,t-j+\bar{J}} \prod_{i=1}^{j-\bar{J}} (1 + r^I_{t-j+\bar{J}+i})} \tag{30}$$

$$\tau_t = \frac{\sum_{j=\bar{J}_t}^{J} N_{j,t}\rho_1 \cdot w_{avg,t-j+\bar{J}} \prod_{i=1}^{j-\bar{J}} (1 + r^I_{t-j+\bar{J}+i})}{w_t L_t} \tag{31}$$

It follows that in the PAYG DB system, with a changing ratio between retired population $\sum_{j=\bar{J}_t}^{J} N_{j,t}$ and working population $\sum_{j=1}^{\bar{J}_t} N_{j,t}$, either $b_{j,t}$ or $\tau_{j,t}$ has to adjust.

We consider two closures: contribution rate and benefits. In the **contribution** closure (τ), we record the effective contribution rate from the inital steady state and impose it on the transition path of the baseline and reform scenario. Whatever additional contribution is needed to balance the pension system is collected from the agents. In the baseline scenario it increases effective labor taxation. In the reform scenario, additional contributions would have translated to increased future pension benefits, following equations (6) and (8), i.e. postpone the imbalance, but not solve it. To avoid that, we treat the "additional" contribution as a one that does not enter $f^I_{j,t}$, nor $f^{II}_{j,t}$. In practice this is equivalent to increased labor taxation in the reform scenario (and positive implicit tax nested in the pension system until the end of the transition). In the **benefits** closure, we compute the proportion of the retirement benefits that needs to be taxed away to balance the pension system in the reform scenario, independently of the analogous tax computed in the baseline scenario. A balanced pension system does not imply a balanced government budget due to the second order general equilibrium effects of the demographic change. We use lump sum tax Υ_t.

Tax closures Either of the two taxes – on labor on consumption – adjusts immediately in each period to balance the pension system. It implies

$$\tau_{c,t} = \frac{G_t + subsidy_t + r_t D_t - \Upsilon_1 \sum_{j=1}^{J} N_{j,t} - \tau_{l,1}(1-\tau_1) w_t L_t - \tau_k r_t A_t - \Delta D_t}{C_t} \tag{32}$$

$$\tau_{l,t} = \frac{G_t + subsidy_t + r_t D_t - \Upsilon_1 \sum_{j=1}^{J} N_{j,t} - \tau_{c,1} C_t - \tau_k r_t A_t - \Delta D_t}{(1-\tau_1) w_t L_t}. \tag{33}$$

In the baseline scenario we compute the values of $\tau_{c,t}$, $\tau_{l,t}$, replicating the design of the capital income tax closure discussed earlier. In parallel to the combination of capital income tax and public debt, we also consider a combination of $\tau_{c,t}$ and $\tau_{l,t}$ with the public debt. By analogy to equation (34) we assume the following fiscal rule (with identical notation):

$$\tau_{tax,t} = (1-\varrho)\tau_{tax}^{final} + \varrho\tau_{tax,t-1} + \varrho_D \left(D/Y_t - D/Y^{final}\right) \forall tax \in l, c. \tag{34}$$

The difference between the labor tax closure described by equations (33) or (34) and the closure which adjusts the contribution rate described by equation (31) concerns the use of the lump sum tax, Υ_t. In fiscally neutral closures within the pension system, we use the lump sum tax to balance the government which is necessary due to the general equilibrium effects of changing demographics, technological progress, and incentives from the pension system. In the labor tax closures, the lump sum tax is constant from the initial steady state, whereas all the general equilibrium effects are captured by adjustments in τ_l. By comparing these two scenarios we can gauge the size of these second order effects.

C Model calibration

Figure A1: Labor tax progressivity: marginal labor income tax function

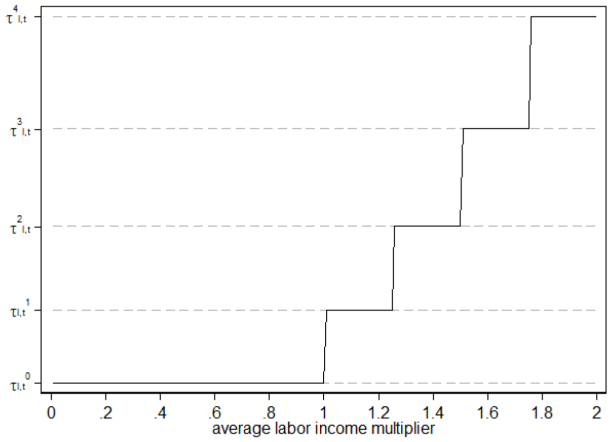
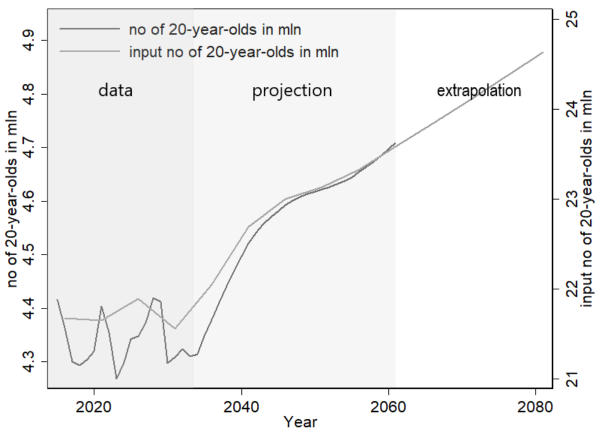
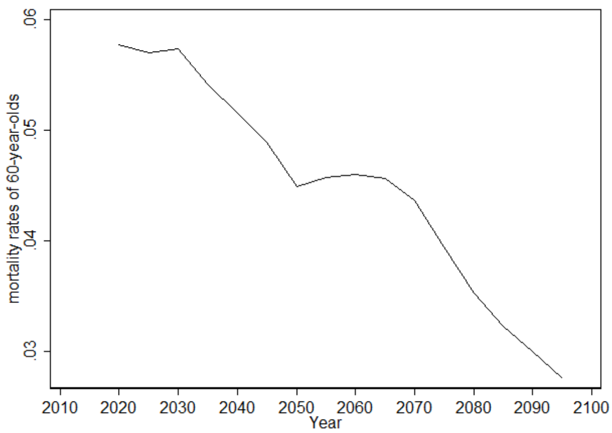


Figure A2: Number of 20-year-olds arriving in the model in each period, 5 years mortality rates across time for 60-year-olds.



(a) number of 20-year-olds



(b) mortality rates

Table A2: Calibrated parameters for the initial steady state

	Macroeconomic parameters	Calibration	Target	Value (source)
ϕ_l	preference for leisure	2.268	average hours	33% BEA(NIPA)
ϕ_g	preference for public consumption	0.263	optimal *per capita* value	
δ	discounting rate	1.006	interest rate	4%
d	one year depreciation rate	0.013	investment rate	25% BEA(NIPA)
τ_l	labor tax	0.150	revenue as % of GDP	9.2% OECD
τ_c	consumption tax	0.065	revenue as % of GDP	3.8% OECD
τ_k	capital tax	0.130	revenue as % of GDP	3.6% OECD
ρ	replacement rate	0.215	benefits as % of GDP	5.2% K&K
τ	social security contr.	0.078	balanced pension system	
	income shocks			
ϱ_η	shock persistence	0.774	K&O	
σ_η	shock variance	0.170	K&O	
	fiscal rule parameters			
ϱ	tax rate persistence	0.800		
ϱ_D	strength of debt-tax link	0.300		

Notes: K&O denotes Krueger and Ludwig (2013), K&K denotes Kindermann and Krueger (2014)

Table A3: Tax revenue

	Macroeconomic parameters	Calibration	OECD code	revenue as % of GDP
τ_l	labor tax	0.150	1110	9.2%
τ_c	consumption tax	0.065	5000 - {5122, 5126, 5210}	3.8%
τ_k	capital tax	0.130	1120, 4000	3.6%

Notes: We calibrate taxes share in GDP as 5 year averages.

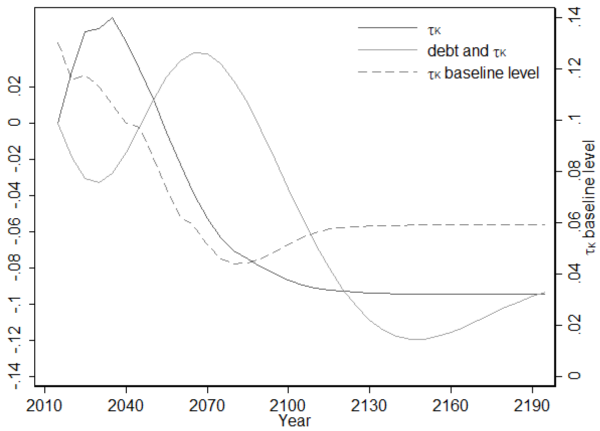
D Results for the main macroeconomic indicators

Table A4: Macroeconomic effects

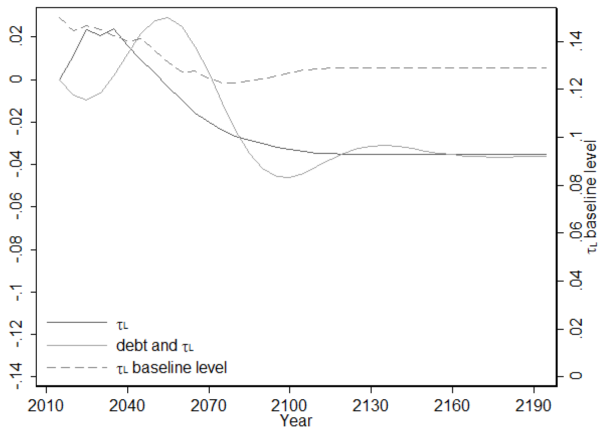
Macroeconomic indicators	Fiscal closure for baseline and reform								
	τ_k	$debt\tau_k$	progression	τ	pension (τ_b)	τ_c	τ_l	$debt\tau_c$	$debt\tau_l$
	Final steady state relative to the initial steady state value (baseline scenario)								
aggregate labor [a]	166	166	164	165	166	166	166	166	166
aggregate K/L [a]	14.79	14.79	14.70	14.58	14.98	14.70	14.72	14.70	14.72
interest rate [b]	-0.42	-0.42	-0.40	-0.38	-0.46	-0.40	-0.40	-0.41	-0.41
	Change in aggregate labor in reform scenario as a % deviation from baseline								
2020	6.67	8.29	7.69	6.43	6.70	7.34	7.72	8.00	8.34
2040	8.50	7.94	8.05	7.22	7.32	8.49	8.01	8.18	8.23
2060	9.05	8.12	9.50	7.89	7.43	9.15	9.15	8.67	7.52
$+\infty$	8.61	8.61	9.86	7.66	7.07	9.21	9.23	9.21	9.23
	Change in aggregate capital in reform scenario as a % deviation from baseline								
2020	n.a.[c]								
2040	9.03	9.40	9.52	7.94	11.98	11.84	9.82	8.31	10.43
2060	18.64	12.53	16.98	13.87	16.55	19.01	17.13	16.66	15.48
$+\infty$	30.79	30.79	27.46	21.30	17.42	22.13	26.79	22.13	26.79
	Change in (annual) interest rate in reform scenario in p.p. deviation from baseline								
2020	0.23	0.25	0.25	0.22	0.21	0.24	0.26	0.25	0.27
2040	-0.01	-0.02	-0.04	-0.14	-0.02	-0.10	-0.01	-0.06	-0.07
2060	-0.21	-0.08	-0.20	-0.24	-0.15	-0.25	-0.21	-0.20	-0.20
$+\infty$	-0.38	-0.38	-0.36	-0.24	-0.30	-0.28	-0.28	-0.36	-0.36

Note: Results report aggregate labor and capital as a % change between reform and baseline, when the same fiscal closure is assumed in both baseline and reform scenarios, equivalent to the diagonal of Table 1 and Table 2. Calibration presented in Table A2.
[a] – expressed in % of the initial steady state
[b] – expressed in pp. difference to initial steady state
[c] – by construction, there is no change in capital in the first period
Closure τ denotes the situation in which contribution rate is adjusting to make the pension system fiscally neutral, as in equation (31). Closure *pension* (τ_b) refers to reduction in pension benefits to assure pension system balance, see equation (31). Closures τ_c, τ_l and τ_k stand for immediate adjustment of consumption, labor and capital income tax respectively, see with equations (32) and (33). Tax progressivity closure is indicated as *progression*, see equations (24) - (25). Closures *debt* τ_c, *debt* τ_l and *debt* τ_k permit the use of public debt as a resource for financing pension system reform. To avoid public debt explosion, fiscal rule described in the equation (23) is applied.

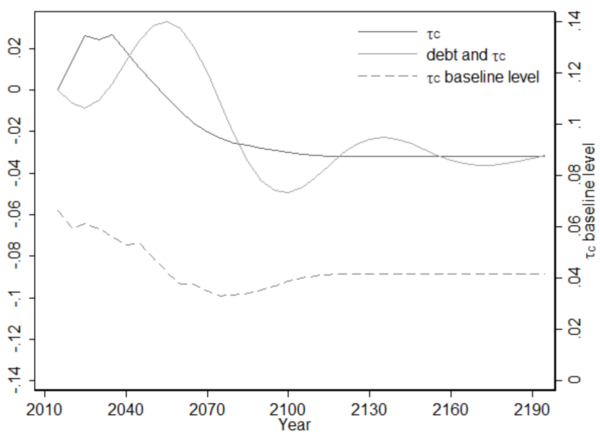
Figure A3: capital, labor income and consumption tax



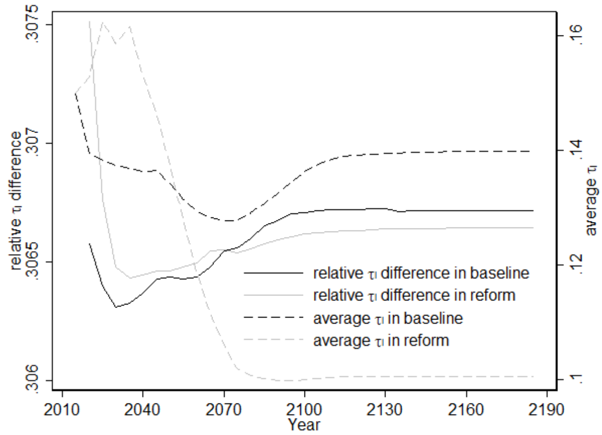
(a) τ_k - capital income



(b) τ_l - labor income



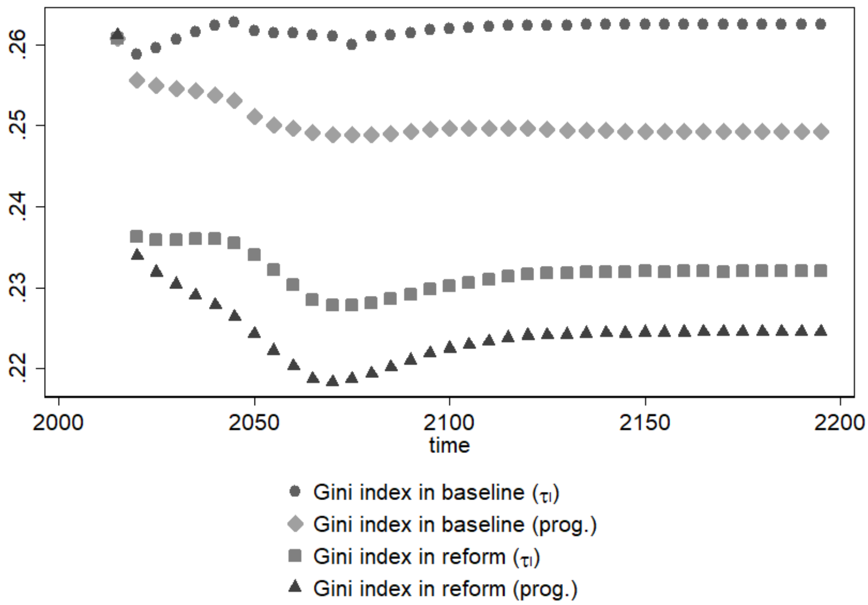
(c) τ_c - consumption



(d) progressive τ_l - labor

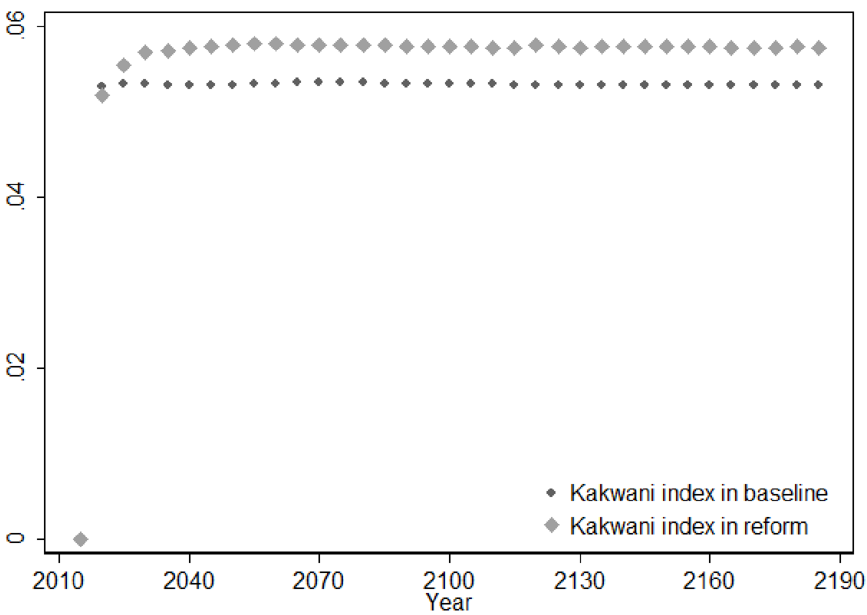
Notes: in panels (a)-(c) tax rates are expressed as p.p. difference between reform and baseline scenario. In panel (d) average labor tax rate (right axis) and the relative difference between $\tau^4_{l,t}$ and $\tau^0_{l,t}$ for baseline and reform (left axis). Note that unlike panels (a)-(c), the left axis of panel (d) is expressed in level terms, not in difference terms, for clarity.

Figure A4: Gini index in the baseline and reform scenario



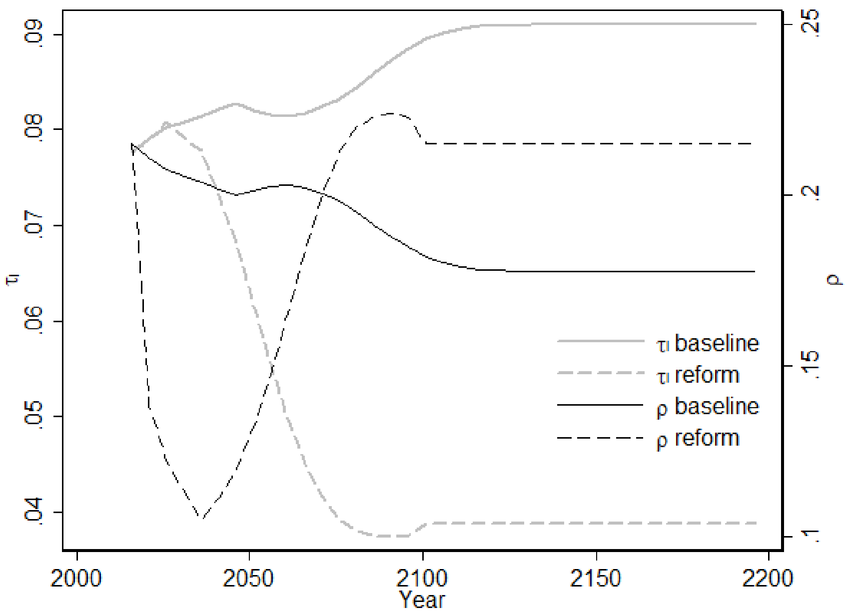
Note: Analogous policy options in the baseline and reform scenarios for adjustment in τ_l and progressive labor income tax.

Figure A5: Kawani index in the baseline and reform scenario for progressive labor income tax



Note: Analogous policy options in the baseline and reform scenarios.

Figure A6: Adjustments of the pension system's parameters in the baseline and the reform scenario



Note: Analogous policy options in the baseline and reform scenarios.

E Full set of results

Table A5: Welfare effects – the full set of results from Tables 3 and 4

Fiscal closure		Baseline								
		τ_k	$debt\tau_k$	progression	τ	pensions (τ_b)	τ_c	τ_l	$debt\tau_c$	$debt\tau_l$
		Welfare effects – final steady state (in % of lifetime consumption)								
Reform	τ_k	0.85	0.85	1.25	0.89	0.66	0.92	0.91	0.92	0.91
	$debt\tau_k$	0.84	0.84	1.25	0.88	0.65	0.91	0.91	0.91	0.91
	progression	-0.11	-0.11	0.32	0.21	0.13	-0.03	-0.03	-0.03	-0.03
	τ	0.13	0.13	0.56	0.36	0.27	0.21	0.21	0.21	0.21
	pensions (τ_b)	0.12	0.12	0.55	0.35	0.26	0.20	0.20	0.20	0.20
	τ_c	0.03	0.03	0.46	0.32	0.25	0.11	0.11	0.11	0.11
	τ_l	-0.14	-0.14	0.29	0.20	0.14	-0.07	-0.07	-0.07	-0.06
	$debt\tau_c$	0.02	0.02	0.45	0.31	0.24	0.10	0.10	0.10	0.10
	$debt\tau_l$	-0.14	-0.14	0.29	0.20	0.14	-0.06	-0.06	-0.06	-0.06
		Welfare effects – aggregate (in % of lifetime consumption)								
Reform	τ_k	0.83	0.83	1.23	0.77	0.54	0.90	0.89	0.89	0.89
	$debt\tau_k$	0.82	0.82	1.23	0.75	0.52	0.89	0.89	0.89	0.89
	progression	-0.32	-0.32	0.12	-0.05	-0.08	-0.24	-0.24	-0.24	-0.23
	τ	-0.14	-0.13	0.31	0.08	0.08	-0.05	-0.04	-0.05	-0.04
	pensions (τ_b)	-0.15	-0.15	0.30	0.07	0.06	-0.07	-0.06	-0.07	-0.06
	τ_c	-0.18	-0.18	0.27	0.08	0.08	-0.09	-0.09	-0.10	-0.08
	τ_l	-0.34	-0.33	0.10	-0.03	-0.05	-0.25	-0.25	-0.25	-0.25
	$debt\tau_c$	-0.21	-0.21	0.24	0.06	0.06	-0.12	-0.11	-0.12	-0.11
	$debt\tau_l$	-0.33	-0.33	0.11	-0.04	-0.05	-0.25	-0.25	-0.25	-0.25
		Political majority (in % of voters benefiting from the reform)								
Reform	τ_k	35	43	58	35	43	35	43	43	43
	$debt\tau_k$	58	66	82	58	58	58	66	58	74
	progression	35	43	43	43	43	35	43	43	43
	τ	58	58	66	58	58	58	58	58	58
	pensions (τ_b)	0	0	0	0	0	0	0	0	0
	τ_c	35	43	43	35	43	35	43	35	43
	τ_l	43	43	50	43	50	43	43	43	43
	$debt\tau_c$	43	50	58	43	50	43	50	43	50
	$debt\tau_l$	43	58	58	58	58	43	58	50	58

Note: Results report aggregate welfare effects for all cohorts, equation (28). Political support is computed as a fraction of cohorts living in the first year (steady state) benefiting from the reform. Closure τ denotes the situation in which contribution rate is adjusting to make the pension system fiscally neutral, as in equation (31). Closure τ_b refers to the situation in which pension benefits are reduced to ensure pension system balance, see equation (31). Closures τ_c, τ_l and τ_k stand for immediate adjustment of consumption, labor and capital income tax respectively, compare with equations (32), (33) and (22). Tax progressivity closure is indicated as *progression*, see equations (24) - (25). Closures *debt* τ_c, *debt* τ_l and *debt* τ_k permit the use of public debt to temporarily fund the costs of the pension system reform, with fiscal rule described in equation (23).

F Deterministic model

We compare the results from a stochastic model – preferred specification in this study – with a deterministic model. The replication of the macroeconomic outcomes from the data in a deterministic setup requires a recalibration relative to a stochastic setup. Hence. we report how the calibration had to change. We report the results from a recalibrated deterministic model and a deterministic model with the same parameters as the stochastic one. Expectedly, welfare gains are larger and political support broader in the case of the deterministic setup. Tax progressivity closure was omitted from the comparisons, because in a deterministic setup the only driver of earned income heterogeneity is age.

Table A6: Comparison between parameters calibrated for the stochastic and deterministic model, initial steady state

	Macroeconomic parameters	Stochastic calibration	Deterministic recalibration
ϕ_l	preference for leisure	2.268	2.770
δ	discounting rate	1.006	1.007
d	one year depreciation rate	0.013	0.013
τ_l	labor tax	0.150	0.149
τ_c	consumption tax	0.065	0.065
τ_k	capital tax	0.130	0.126
ρ	replacement rate	0.215	0.265
τ	social security contr.	0.078	0.078
	income shocks		
ϱ_η	shock persistence	0.774	-
σ_η	shock variance	0.170	-
	fiscal rule parameters		
ϱ	tax rate persistence	0.800	0.800
ϱ_D	strength of debt-tax link	0.300	0.300

Table A7: Welfare effects for deterministic model, original calibration

Fiscal closure		Baseline τ_k	$debt\tau_k$	τ	τ_b	τ_c	τ_l	$debt\tau_c$	$debt\tau_l$
		Welfare effects – final steady state							
Reform	τ_k	3.25	3.25	3.27	3.12	3.34	3.35	3.34	3.35
	$debt\tau_k$	3.24	3.24	3.26	3.11	3.33	3.34	3.33	3.34
	τ	2.21	2.21	2.49	2.42	2.30	2.32	2.31	2.32
	pensions (τ_b)	2.21	2.22	2.49	2.43	2.31	2.32	2.31	2.33
	τ_c	2.70	2.70	2.85	2.75	2.80	2.81	2.80	2.81
	τ_l	3.25	3.25	3.27	3.12	3.34	3.35	3.34	3.35
	$debt\tau_c$	2.69	2.69	2.85	2.74	2.78	2.80	2.79	2.80
	$debt\tau_l$	2.57	2.58	2.76	2.67	2.67	2.68	2.67	2.68
		Welfare effects – aggregate							
Reform	τ_k	2.89	2.90	2.88	2.79	3.00	3.02	3.00	3.02
	$debt\tau_k$	2.87	2.88	2.86	2.77	2.98	2.99	2.98	3.00
	τ	1.78	1.80	2.07	2.07	1.90	1.93	1.90	1.94
	pensions (τ_b)	1.79	1.81	2.08	2.09	1.91	1.94	1.92	1.95
	τ_c	2.28	2.30	2.44	2.41	2.40	2.43	2.40	2.44
	τ_l	2.07	2.08	2.28	2.26	2.19	2.21	2.19	2.22
	$debt\tau_c$	2.26	2.27	2.42	2.40	2.38	2.40	2.38	2.41
	$debt\tau_l$	2.07	2.09	2.29	2.27	2.19	2.21	2.19	2.22
		Political support (%)							
Reform	τ_k	99	99	99	99	99	99	97	99
	$debt\tau_k$	99	99	99	99	99	99	97	99
	τ	99	99	99	99	99	99	97	99
	pensions (τ_b)	99	99	99	99	99	99	97	99
	τ_c	99	99	99	99	99	99	97	99
	τ_l	99	99	99	99	99	99	97	99
	$debt\tau_c$	41	55	41	41	48	41	41	55
	$debt\tau_l$	99	99	99	99	99	99	97	99

Note: In a deterministic model all agents are equal within their birth cohorts, hence no progressive taxation applies. Results report aggregate welfare effects for all cohorts, equation (28). Political support is computed as a fraction of cohorts living in the first year (steady state) benefiting from the reform. Closure τ denotes the situation in which contribution rate is adjusting to make the pension system fiscally neutral, as in equation (31). Closure τ_b refers to the situation in which pension benefits are reduced to ensure pension system balance, see equation (31). Closures Closures τ_c, τ_l and τ_k stand for immediate adjustment of consumption, labor and capital income tax respectively, compare with equations (32), (33) and (22). Closures *debt* τ_c and *debt* τ_l permit the use of public debt to temporarily fund the costs of the pension system reform, with fiscal rule described in equation (23).

Table A8: Welfare effects for deterministic model, recalibration

Fiscal closure		Baseline							
		τ_k	$debt\tau_k$	τ	τ_b	τ_c	τ_l	$debt\tau_c$	$debt\tau_l$
		Welfare effects – final steady state							
Reform	τ_k	4.02	4.02	3.93	3.40	4.03	4.03	4.03	4.04
	$debt\tau_k$	4.01	4.01	3.91	3.39	4.02	4.02	4.02	4.03
	τ	2.45	2.46	2.88	2.63	2.48	2.49	2.88	2.49
	pensions (τ_b)	2.46	2.47	2.89	2.64	2.50	2.50	2.50	2.50
	τ_c	3.22	3.23	3.39	3.02	3.26	3.26	3.26	3.27
	τ_l	3.03	3.03	3.26	2.92	3.06	3.06	3.06	3.06
	$debt\tau_c$	3.21	3.22	3.38	3.01	3.25	3.25	3.25	3.26
	$debt\tau_l$	3.03	3.03	3.27	2.92	3.06	3.06	3.06	3.07
		Welfare effects – aggregate							
Reform	τ_k	3.75	3.75	3.54	3.10	3.79	3.79	3.78	3.79
	$debt\tau_k$	3.72	3.73	3.51	3.07	3.76	3.77	3.76	3.77
	τ	1.96	1.98	2.39	2.30	2.03	2.04	2.03	2.05
	pensions (τ_b)	1.98	2.00	2.41	2.32	2.06	2.07	2.06	2.08
	τ_c	2.75	2.77	2.90	2.70	2.82	2.83	2.82	2.84
	τ_l	2.48	2.49	2.72	2.53	2.54	2.55	2.54	2.56
	$debt\tau_c$	2.72	2.74	2.87	2.68	2.80	2.81	2.80	2.81
	$debt\tau_l$	2.48	2.49	2.72	2.53	2.54	2.55	2.54	2.56
		Political majority (%)							
Reform	τ_k	99	99	99	99	99	99	99	99
	$debt\tau_k$	99	99	99	99	99	99	99	99
	τ	99	99	99	99	99	99	99	99
	pensions (τ_b)	99	99	99	99	99	99	99	99
	τ_c	99	99	99	99	99	99	99	99
	τ_l	99	99	99	99	99	99	99	99
	$debt\tau_c$	41	41	33	33	41	33	41	41
	$debt\tau_l$	99	99	99	99	99	99	99	99

Note: In a deterministic model all agents are equal within their birth cohorts, hence no progressive taxation applies. Results report aggregate welfare effects for all cohorts, equation (28). Political support is computed as a fraction of cohorts living in the first year (steady state) benefiting from the reform. Closure τ denotes the situation in which contribution rate is adjusting to make the pension system fiscally neutral, as in equation (31). Closure τ_b refers to the situation which pension benefits are reduced to ensure pension system balance, see equation (31). Closures Closures τ_c, τ_l and τ_k stand for immediate adjustment of consumption, labor and capital income tax respectively, compare with equations (32), (33) and (22). Closures *debt* τ_c and *debt* τ_l permit the use of public debt to temporarily fund the costs of the pension system reform, with fiscal rule described in equation (23).

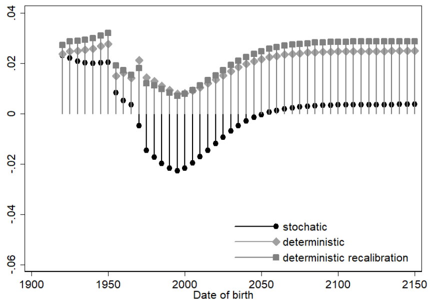
Table A9: Welfare effects for alternative labor productivity assumptions

Fiscal closure		Baseline								
		τ_k	$debt\tau_k$	progression	τ	pensions (τ_b)	τ_c	τ_l	$debt\tau_c$	$debt\tau_l$
		Welfare effects – final steady state (in % of lifetime consumption)								
Reform	τ_k	0.69	0.69	1.33	1.09	0.90	1.14	1.07	1.14	1.07
	$debt\tau_k$	0.67	0.67	1.31	1.06	0.87	1.12	1.05	1.12	1.05
	progression	-0.17	-0.16	0.49	0.60	0.48	0.27	0.23	0.28	0.23
	τ	-0.01	-0.01	0.65	0.69	0.57	0.41	0.39	0.42	0.39
	pensions (τ_b)	-0.03	-0.02	0.64	0.67	0.56	0.40	0.37	0.40	0.37
	τ_c	-0.11	-0.11	0.55	0.68	0.57	0.31	0.29	0.31	0.29
	τ_l	-0.16	-0.15	0.50	0.65	0.53	0.29	0.24	0.29	0.24
	$debt\tau_c$	-0.14	-0.13	0.53	0.66	0.55	0.29	0.26	0.29	0.26
	$debt\tau_l$	-0.15	-0.16	0.51	0.62	0.46	0.29	0.25	0.28	0.23
		Welfare effects – aggregate (in % of lifetime consumption)								
Reform	τ_k	0.42	0.42	1.08	0.65	0.53	0.83	0.82	0.83	0.82
	$debt\tau_k$	0.38	0.38	1.04	0.59	0.48	0.78	0.78	0.79	0.78
	progression	-0.66	-0.65	0.04	0.04	0.02	-0.27	-0.24	-0.27	-0.24
	τ	-0.42	-0.40	0.29	-0.02	0.19	-0.07	0.01	-0.06	0.01
	pensions (τ_b)	-0.45	-0.43	0.26	0.17	0.16	-0.09	-0.02	-0.09	-0.02
	τ_c	-0.41	-0.40	0.30	0.25	0.24	-0.06	0.02	-0.05	0.02
	τ_l	-0.64	-0.63	0.06	0.12	0.11	-0.25	-0.22	-0.25	-0.22
	$debt\tau_c$	-0.45	-0.44	0.26	0.21	0.20	-0.10	-0.03	-0.10	-0.03
	$debt\tau_l$	-0.63	-0.63	0.07	0.04	0.13	-0.24	-0.21	-0.27	-0.22
		Political majority (in % of voters benefiting from the reform)								
Reform	τ_k	35	35	58	35	43	35	43	35	43
	$debt\tau_k$	58	58	91	58	58	66	82	74	82
	progression	35	35	43	43	43	35	43	35	43
	τ	58	58	66	0	58	58	58	58	58
	pensions (τ_b)	0	0	0	0	0	0	0	0	0
	τ_c	35	35	50	35	43	35	43	35	43
	τ_l	43	35	43	43	43	43	43	43	43
	$debt\tau_c$	43	43	58	43	50	43	50	43	50
	$debt\tau_l$	43	43	58	58	58	43	58	43	50

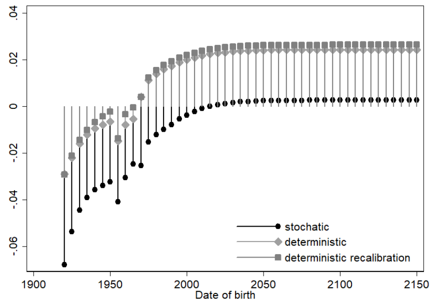
Note: Results report aggregate welfare effects for all cohorts, equation (28). The constant γ scenario assumes 2% per annum throughout the entire simulation. The declining γ scenario assumes 2% per annum in the initial steady state gradually declining to 1.5% over the period of 55 years (11 model periods) and stabilizes at 1.5% per annum thereafter. Political support is computed as a fraction of cohorts living in the first year (steady state) benefiting from the reform. Closure τ denotes the situation in which contribution rate is adjusting to make the pension system fiscally neutral, as in equation (31). Closure τ_b refers to situation in which pension benefits are reduced to ensure pension system balance, see equation (31). Closures τ_c and tau_l stand for immediate adjustment of consumption and labor tax respectively, compare with equations (32) and (33). Closures *debt* τ_c and *debt* τ_l permit the use of public debt to temporarily fund the costs of the pension system reform, with fiscal rule described in equation (23).

Figure A7: Consumption equivalents – comparison between stochastic and deterministic models (% of permanent consumption in reform scenario)

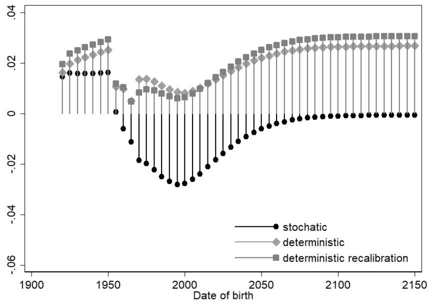
(a) τ - contribution rate



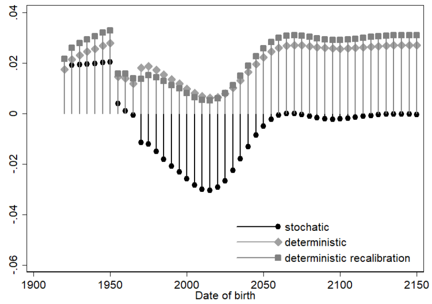
(b) τ_b - pension benefits



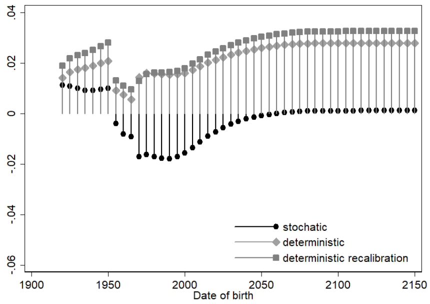
(c) τ_l - labor tax



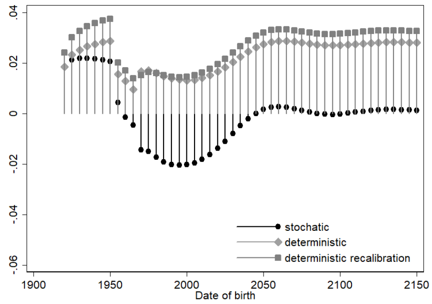
(d) debt τ_l - public debt



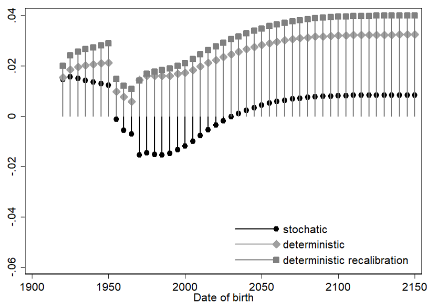
(e) τ_c - consumption tax



(f) debt τ_c - public debt



(g) τ_k - capital income tax



(h) debt τ_k - public debt