Welfare effects of fiscal policy in reforming the pension system*

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Abstract

Most reforms of the pension systems imply substantial redistribution 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.

Key words: pension system reform, fiscal policy, welfare effects

JEL Codes: 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. There are two major forces putting a strain on pension systems: longevity and declining fertility. Both these processes contribute to the increase of the dependency ratio in the US, Europe, Japan and emerging economies alike (Diamond 2004). These trends call for a reform in pensions: systemic and/or parametric. The former consists of replacing the defined benefit system financed typically on a pay-as-you-go basis (PAYG DB) with a defined contribution (DC), partially or fully funded.[1] The latter boils down to adjusting selected parameters of the existing existing defined benefit systems: eligibility conditions (e.g. retirement age), contribution rate or replacement rate.

The aggregate welfare effects of parametric and systemic reforms as well as their distribution across cohorts are not obvious. Taking the example of a systemic reform, a DC system links benefits to contributions, thus yielding efficiency gains because the pension system contributions become less distortionary. By contrast, replacing a DB system with a DC typically lowers the insurance provided by the pension system if income is subject to idiosyncratic shocks. Moreover, (partial) funding of the social security is likely to generate a superior accrual of old-age savings, relative to the typical indexation rate of the payroll growth in pay-as-you-go pillars. Yet, with even only partial funding, there is a transition period where working population has to both pay for the contemporaneous old-age benefits and to save for their own pensions. Parametric adjustments too are likely to generate inter-generational transfers. Finally, the adjustments in the pension system are made with the objective to reduce the strain on public finance. For a given type of the pension system reform, the way of the fiscal adjustment may generate fiscal effects on its own. Since these effects work in opposite directions, the assumptions about the character of the reform and the fiscal adjustment matter for the final outcomes. Weighting all these factors provides mixed results in the literature concerning the welfare effect of the pension system reforms.

There is a large body of literature that analyzes the effects of systemic pension system reform in the overlapping generations (OLG) framework (see the reviews by Lindbeck and Persson 2003, Fehr 2009, 2016). The literature argues a transition to (partially) funded defined contribution system generates welfare improvement relative to pay-as-you-go defined benefits system in the context of longevity and decreasing fertility (Diamond 2004, Fehr 2016). The extent of efficiency gain may depend on a number of factors including the extent of time inconsistency (Imrohoroglu et al. 2003,

[1]Introduction of the (partial) funding is referred to as privatization of the social security (Diamond et al. 2016).

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. When intragenerational redistribution is taken into account by augmenting the OLG model with idiosyncratic income shocks, the welfare loss due to lower insurance against adverse income shocks may outweigh the efficiency gains (see Davidoff et al. 2005, Nishiyama and Smetters 2007, Fehr et al. 2008, Harenberg and Ludwig 2016).

While the profession has developed relatively coherent standards as to how this class of economic models should be built, there is much less consistency in the way the reforms are formulated and financed. The literature differs substantially what type of fiscal adjustment is used to balance the pension expenditures and changes thereof. For example, Auerbach and Kotlikoff (1987) adjusts the contribution rates, whereas Fehr et al. (2008), Keuschnigg et al. (2012), Fehr and Kindermann (2010), Ludwig and Vogel (2009) interchangeably employ tax and contribution rate adjustments. By contrast, Nishiyama and Smetters (2007), Okamoto (2005) use a lump-sum tax. Table A1 summarizes examples of the studies devoted to parametric and pension system reform, synthesizing the stark differences in the modeling options. One of the reasons, as may be understood from Fehr (2009), is the fact that these models focus on relatively fundamental questions (efficiency of the potential reform and the role of the demographics), leaving aside "technicalities" such as fiscal policy. Pension systems are largely a political – not only policy – matter.

Hence, there is also a number of attempts to comprise in OLG models a political economy component and test the political stability of the reform with the changing demographics, cfr. Galasso (1999), Kumru and Piggott (2010), Wright et al. (2012). Notably, while the fiscal closure is likely to generate fiscal effects on its own, only a handful of studies provides sensitivity analyses of the results to the various fiscal scenarios. An adjustment most widely employed by the governments – raising public debt – has rarely been analyzed. Importantly, temporary increase of the public debt spreads the costs of the reform over a larger number of generations, effectively replacing a large distortion for a small number of cohorts with a smaller distortion for a larger number of cohorts. Hence, bringing it to the analysis is interesting also from an academic perspective.

Our study aims at bridging this gap. In an OLG economy, unlike a representative agent economy, no fiscal instrument is welfare neutral. Each fiscal instrument weighs different aspects of the reform, because it implicitly redistributes between cohorts, therefore affecting the final result. This feature is stronger if intragenerational heterogeneity is taken into account. At the same time, the size of necessary fiscal adjustment may indeed be large. Some papers argue a necessary increase in taxation of roughly 40% to provide for pension system imbalance (Braun and Joines 2015) or a 40% reduction in replacement rates to maintain fiscal neutrality of the pension system (Fehr 2000).

Substantial increase in taxes has immediate welfare effects, on top of the welfare effects induced by the pension system reform (e.g. Kotlikoff et al. 1999, Huggett and Ventura 1999, Genakoplos et al. 2000). Indeed, in a deterministic context and for some selected policy options, Makarski et al. (2017) show that the magnitude of the welfare effect in the case of a systemic reform depends substantially on a fiscal closure.

Against a rich body of literature, our objective is to provide a comprehensive overview of the consequences from the assumed fiscal instruments on the welfare effects of the social security reforms. We construct an OLG model in the spirit of Auerbach and Kotlikoff (1987) with households facing idiosyncratic income shocks, production sector, pension system and fiscal sector. The model is calibrated to the US economy. The economy is subjected to longevity, declining fertility, following the projections for the US economy. In the initial steady state economy has a defined benefit system financed on a pay-as-you-go basis (DB PAYG). This economy is unexpectedly subjected to a systemic change in the pension system: we introduce a defined contribution system with partial financing. Against this systemic change we compare a wide variety of fiscal adjustments. First, we consider the adjustments which contain all the transition costs in the pension system: we adjust contribution rates, or pension benefits. Second, we also consider the adjustments in which the government needs to finance pension system imbalances: we adjust tax rates, tax progression, public expenditure and public debt. In total, we consider 8 cases for the adjustment in the baseline scenario of no policy change (PAYG DB) and 8 cases of the reform scenario of systemic reform of the social security (introducing a partially funded DC).

We find that the choice of policy complementary to the systemic reform of pensions is of paramount importance to both short term and long-term welfare effects. The solutions prefered 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 these policy options which make reforms detrimental to welfare in the long run. Specifically, the adjustment in the public expenditure is the most beneficial in the long run, but cannot obtain public support. By contrast, the standard policy options discussed in public debates and analyzed in the earlier literature may obtain public support, but have negative aggregate welfare effects. Nearly all policy options provide welfare gains in the long run, but the perspective of these gains is indeed distant.

Our paper contributes to the literature along two margins. The first margin may appear as technical: we provide a systematic overview of the interaction between the pension system reform and policy menu available to the governments implementing such reforms. This review responds to a variety of actual policies implemented in various countries. It also exceeds a purely technical exercise, because it yields results relevant for policy makers. The second margin is methodological: we propose to consider new ways of financing the pensions system reform: public spending and tax progression. These two solutions prove to improve welfare the most in aggregate terms and in the long-run, but in the short run may be unable to obtain sufficient political support.

The paper is structured as follows. 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 sections conclude emphasizing 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 aging process. As population ages the deficit in the PAYG DB pension system grows. The policy options are dual: either parameters of the pension system have to change or fiscal adjustment is needed. We compare the results from a number of possible policy options. The first set of policy options is fiscally neutral: we adjust replacement rate or contribution rate for the pension system to remain balanced. The second set of policy options leaves pension system intact, adjusting taxes, public debt or government spending in order to balance the pension system.

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.

In order to compare the effects of the pension system reform, we run for each possible policy option a baseline scenario of no change in the pension system and a reform scenario of gradual replacement of DB with DC and partial funding. We compare the welfare of the baseline and the reform for all agents in the steady states and along the transition path.

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 the age of 20, which we denote $j = 1$ to abstract from the problem of the labor market entry timing as well as educational choices. 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 is eventually treated as stable in the final steady state, with yearly population growth equals 1.002.[2] In each period t agents at the age of $j = \bar{J}$ retire.

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 The agent's income is composed of the labor earnings $w_{j,t} = \omega_{j,t}\bar{w}_t$.[3] In addition to salary, income consists also of after-tax capital gain $r_t a_{j,t}$ and pension benefits $b_{j,t}$. There is no income tax on pension benefits. The agent receives unintended, cohort specific bequest $\Gamma_{j,t}$. Income is used to finance contemporaneous consumption $(1+\tau_{c,t})c_{j,t}$ and assets for the future consumption $a_{j+1,t+1}$. There is also a lump sum tax Υ_t, spread equally across living cohorts. Hence, the agents face an instantaneous budget constraint:

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

Preferences An agent of age j in period t consumes $c_{j,t}$, and allocates $l_{j,t}$ time to work. Total time endowment is normalized to one. Agents in our model derive utility from consumption and leisure, as well as government spending on public goods and services g_t expressed in *per capita* terms. The instantaneous utility function is given by

$$u(c_{j,t}, 1-l_{j,t}, g_t) = \log(c_{j,t}) + \phi_l \log(1-l_{j,t}) + \phi_g log(g_t) \quad (2)$$

Including the government expenditure in the utility function allows to analyze the scenarios in which the government adjusts expenditure in response to the changing balance of the pension system.

Intra-cohort heterogeneity An agent enters the economy with no assets ($a_{1,t} = 0$) and an identical within cohort labor productivity $\omega_{1,t} = 1$. However, productivity changes randomly over time, $\omega_{j,t} = e^{\eta_{j,t}}$. A random component $\eta_{j,t}$ follows a first order Markov chain with a transition matrix $\Pi(\eta_{j,t}|\eta_{j-1,t-1})$. Assets markets are incomplete, but agents can partially insure against idiosyncratic wage risk by purchasing assets $a_{j+1,t+1} - a_{j,t}$, which offer a risk-free after-tax interest rate $r_t = (1-\tau_k)\bar{r}_t$

[2] Due to 5 years period it is recalculated, and model input is $n = 1.0104 = 1.002^5$

[3] In one of the fiscal closure we consider progressive income tax. It changes slightly individual and government budget constrain. For details go to the section 2.2

The agent at the state $\psi_{j,t}$ maximizes the expected value of the lifetime utility. We can define an individuals' optimization problem in a recursive form as

$$V(\psi_{j,t}) = \max_{c_{j,t},l_{j,t},a_{j+1,t+1}} u(c_{j,t}, l_{j,t}, g_t) + \delta \frac{\pi_{j+1,t+1}}{\pi_{j,t}} \mathbf{E}\big(V(\psi_{j+1,t+1}) \mid \psi_{j,t}\big) \tag{3}$$

subject to the budget constraint given by (1) as well as $0 \leqslant c_{j,t}$, $0 \leqslant l_{j,t} \leqslant 1$.

Pension system In the initial steady state pension system is a PAYG DB, with an exogenous contribution rate τ_t and an exogenous replacement rate ρ_t. 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. Since pension benefits do not depend on individual lifetime earnings profile, they provide insurance against idiosyncratic income shocks during the working period. The system collects contributions from the working and pays benefits to the retired:

$$b_{\bar{J},t} \quad = \quad \rho \cdot w_{avg,t} \qquad \text{and} \qquad b_{j,t} = (1 + r_t^I) b_{j-1,t-1} \forall j > \bar{J}, \tag{4}$$

where r_t^I is the payroll growth rate. The total contributions collected in period t are given by $\tau_t \bar{w}_t \sum_{j=1}^{\bar{j}} N_{j,t} \int_{\Psi_t} \omega_{j,t}(\psi_{j,t}) l_{j,t}(\psi_{j,t}) dX(\psi_{j,t})$. Hence, the budget constraint of the pension system is given by

$$\sum_{j=\bar{J}_t}^{J} N_{j,t} b_{j,t} \quad = \quad \tau_t \bar{w}_t \sum_{j=1}^{\bar{j}} N_{j,t} \int_{\Psi_t} \omega_{j,t}(\psi_{j,t}) l_{j,t}(\psi_{j,t}) dX(\psi_{j,t}) + subsidy_t, \tag{5}$$

where $subsidy_t$ is the net position of the pension system. Economy continues with PAYG DB in the baseline scenario.

In the reform scenario we introduce a partially funded DC system. Implementation is gradual. Individuals born in the year of reform and later participate in a (partially) funded DC system (DC). However, individuals retired before the introduction of the reform or soon thereafter have their pensions disbursed by the old pension system. Hence, for a period of time, a share of the contributions that goes to the DC PAYG pillar is used to the contemporaneous DB pension benefits. Since part of the contributions goes into the funded DC pillar, reform generates a gap 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. Once the reform is implemented, until the final steady state, two thirds of the contribution go the the PAYG pillar and one third to the funded pillar $\tau_t^I = 0.67\tau_t$ and $\tau_t^{II} = 0.33\tau_t$.

Both the PAYG pillar and the funded pillar provide pension benefits denoted by b^I and b^{II}, respectively. Both pillars are defined contribution, i.e. during working period agents accumulate pension funds, which are converted to an annuity at retirement. Hence, benefits in the reform scenario are computed according to the following formulas:

$$b^I_{\bar{J}_t,t} = \frac{f^I_{\bar{J},t}}{\sum_{s=0}^{J-\bar{J}} \frac{\pi_{\bar{J}+s,t+s}}{\pi_{\bar{J},t}}} \quad \text{and} \quad \forall_{j>\bar{J}} \;\; b^I_{j,t} = (1+r^I_t) b^I_{j-1,t-1} \tag{6}$$

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

PAYG DC pillar uses payroll growth as indexation rate[4], whereas the funded pillar reinvests the funds, hence market interest rate applies. Pension funds accumulate in the DC pillars according to:

$$f^I_{j,t} = (1+r^I_t) f^I_{j-1,t-1} + \tau^I_t w_{j,t} l_{j,t} \tag{8}$$

$$f^{II}_{j,t} = (1+\bar{r}_t) f^{II}_{j-1,t-1} + \tau^{II}_t w_{j,t} l_{j,t} \tag{9}$$

where $\omega_{j,t}$ contains the idiosyncratic income shocks. The indexation rate in the PAYG DC pillar r^I_t is equal to the payroll growth in the economy. Contributions to the funded pillar are invested with the tax-free interest rate $\bar{r}_t$.

We introduce the DC scheme as of 2015, but the implementation is gradual. All cohorts older than 50 ($j > 6$ at $t = 2$) at the time of reform stay in DB pension system. For the transition cohorts who worked prior to the implementation of the reform and are shifted to new scheme, we impute the initial values of $f^I_{j,2}$. This imputation is performed only for the cohorts which were born between 1965-1995. We impute the counter-factual funds using the contribution rate τ^I_2 and formula:

$$\forall j \leqslant 6 \quad \text{at} \quad t = 2 \quad f^I_{j,2} = \sum_{s=2}^{s=j} \tau^I_2 \bar{w}_1 l_{s,1} (1 + \bar{r}^I_1)^{j-s+1} \tag{10}$$

where $j = 6$ corresponds to the maximum age of agents assigned to DC scheme, once the reform is implemented. 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.

[4]The payroll fund grows in the economy following $\frac{\bar{w}_{t-1} z_{t-1} L_{t-1}}{\bar{w}_t z_t L_t} - 1$, where L_t denotes aggregate labor supply.

The government Tax revenue has four sources: labor income tax, capital income tax, consumption tax and lump sum tax. The labor income tax $\tau_{l,t}$, is deducted from earnings sequentially, once pension contribution $(1-\tau_t)$ is accounted for. The capital income tax τ_k is deducted from the capital gain $r_t A_t$. In addition, there is a consumption tax $\tau_{c,t}$ and a lump sum tax Υ_t, equal for all cohorts at time t. Collected taxes finance spending on public goods and services $G_t = g_t \sum_{j=1}^{J} N_{j,t}$, balance the pension system paying $subsidy_t$, as well as cover debt service $(1+r_t)D_{t-1}$ with $\Delta D_t = (1+r_t)D_{t-1} - D_t$. Note that *per capita* public spending is constant over time except for one closure ($g_t = g_1$), see section 2.2.

$$T = \tau_{l,t}(1-\tau_t)\bar{w}_t L_t + \tau_{k,t} r_t A_t + \tau_{c,t} C_t + \Upsilon_t \sum_{j=1}^{J} N_{j,t}, \tag{11}$$

$$T_t = G_t + subsidy_t + \Delta D_t, \tag{12}$$

where L_t, C_t and A_t denote aggregate labor supply, consumption and assets, respectively. 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. We calibrate Υ_t in the initial steady state to match the deficits and debt to maintain long run debt/GDP ratio fixed and keep it unchanged throughout the whole path.

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

$$\bar{r}_t = \alpha K_t^{\alpha-1}(z_t L_t)^{1-\alpha} - d \quad \text{and} \quad \bar{w}_t = (1-\alpha) K_t^{\alpha} z_t^{1-\alpha} L_t^{-\alpha}, \tag{13}$$

2.1 Equilibrium, consumer problem and model solving

The state of an agent is fully characterized by $\psi_{j,t} = (a_{j,t}, \eta_{j,t}, f_{j,t}) \in \Psi_t$. We begin by defining the initial and the final steady states. The transition path between the two equilibria is solved according to the same definition as the steady states.

Definition 1 *Recursive equilibrium*
A recursive competitive equilibrium is a sequence of value functions $\{(V_{j,t}(\psi_{j,t}))_{j=1}^{J}\}_{t=1}^{\infty}$, *policy functions* $\{(c_{j,t}(\psi_{j,t}), l_{j,t}(\psi_{j,t}), a_{j+1,t+1}(\psi_{j,t}))_{j=1}^{J}\}_{t=1}^{\infty}$, *prices* $\{\bar{r}_t, \bar{w}_t\}_{t=1}^{\infty}$, *government policies* $\{\tau_{c,t}, \tau_{l,t}, \tau_{k,t}, \tau_b, g_t, \Upsilon_t, D_t\}_{t=1}^{\infty}$, *aggregate quantities* $\{L_t, A_t, K_t, C_t, Y_t\}_{t=1}^{\infty}$, *pension system characteristics* $\{\tau_t, subsidy_t, \rho\}_{t=1}^{\infty}$ *and a measure of households* Ψ_t *such that:*

- ***consumer problem:*** *for each j and t the value function $V_{j,t}(\psi_{j,t})$ and the policy functions $(c_{j,t}(\psi_{j,t}), l_{j,t}(\psi_{j,t}), a_{j+1,t+1}(\psi_{j,t}), f_{j+1,t+1}(\psi_{j,t}))$ solve the Bellman equation* (3)

- ***firm problem:*** *for each t equation* (13) *is satisfied*

- ***government sector:*** *government constraints* (11) *and* (12) *are satisfied following either of equations described in section 2.2*

- ***markets clear***

$$\text{labor market:} \quad L_t = \sum_{j=1}^{\bar{j}} N_{j,t} \int_{\Psi_t} \omega_{j,t}(\psi_{j,t}) l_{j,t}(\psi_{j,t}) dX(\psi_{j,t}) \tag{14}$$

$$\text{capital market:} \quad A_t = \sum_{j=1}^{J} N_{j,t} \int_{\Psi_t} a_{j,t}(\psi_{j,t}) dX(\psi_{j,t}) \tag{15}$$

$$K_{t+1} = A_t + D_t \tag{16}$$

$$\text{goods market:} \quad C_t = \sum_{j=1}^{J} N_{j,t} \int_{\Psi_t} c_{j,t}(\psi_{j,t}) dX(\psi_{j,t}) \tag{17}$$

$$Y_t = C_t + K_{t+1} - (1-d)K_t + G_t \tag{18}$$

- ***probability measure*** Ψ_t *is consistent with the populations structure, the assumptions about stochastic processes and policy functions.*

We solve the consumer problem with value functions iterations. We interpolate policy and value functions with piece-wise linear functions (using recursive Powell's algorithm). For each discrete $\psi_{j,t}$ we find the optimal consumption and labor supply of the agent using Newton-Raphson method. We discretize the state space $\Psi = \hat{A} \times \hat{F} \times \hat{H}$ with $\hat{A} = \{a^1, ..., a^{n_A}\}$, $\hat{F} = \{f^1, ..., a^{n_F}\}$ and $\hat{H} = \{\eta^1, ..., \eta^{n_H}\}$, where $n_A = n_F = 750$ and $n_H = 3$.

For given initial distribution at age $j = 1$ and transition matrix $\Pi(\eta_{j,t}|\eta_{j-1,t-1})$ and the policy functions $\{a_{j+1,t+1}(\psi_{j,t}), f_{j+1,t+1}(\psi_{j,t}))_{j=1}^{J}\}_{t=1}^{\infty}$ we can compute the distribution in any successive age j and period t. It can be interpreted as a fraction of population for any state at the space Ψ. Once we compute distributions and policy functions for each state, we compute aggregate quantities of consumption, labor and savings. 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 choice, the value of k is updated in order to satisfy market clearing. The procedure is repeated until the difference between k 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 the equilibrium is reached, utilities are computed and discounted to reflect utility at $j = 1$ for all subsequent generations.

2.2 Policy options for fiscal closures and pension system adjustments

We consider a wide array of fiscal closures. The first set of closures is fiscally neutral and necessitates all adjustments within the pension system. Hence, in the baseline PAYG DB scenario we analyze a reduction in pension benefits and an increase in the contribution rate such that the pension system is balanced ($subsidy_t = 0$). The second set of fiscal closures leaves the parameters of the pension system intact, but adjusts taxes, public debt or government spending to accommodate for the changing demography in the baseline scenario and the demography coupled with the pension system reform in the reform scenario.

Fiscally neutral closures Recall that with $subsidy_t = 0$, equation (5) becomes:

$$\sum_{j=\bar{J}_t}^{J} N_{j,t}(1-\tau_{b,t})b_{j,t} = \tau_t \bar{w}_t L_t \qquad \text{or} \qquad \tau_t = \frac{\sum_{j=\bar{J}_t}^{J} N_{j,t} b_{j,t}}{\bar{w}_t L_t} \tag{19}$$

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 in the baseline scenario of PAYG DB: contribution rate and benefits. These closures are translated to the policy options in the following manner:

- in the **contribution** closure, we record the effective contribution rate from the baseline scenario and impose it on the reform scenario; in terms of $f^{I}_{j,t}$ and $f^{II}_{j,t}$ from equations (8) and (9) only the contribution rate from the initial steady state is utilized for funds accumulation, any contribution in excess of this value is utilized to finance the gap; 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 to balance the pension system in the reform scenario, independently of the analogous tax computed in the baseline scenario;

Balanced pension system does not imply a balanced government budget due to the demographic changes and general equilibrium effects. We use lump sum tax Υ_t as a fiscal closure.

Tax closure Either of the three taxes – on labor on consumption or on capital income – adjusts immediately in each period to balance the pension system. It implies

$$\tau_{c,t} = \frac{G_t + subsidy_t + \Delta D_t - \Upsilon_1 \sum_{j=1}^{J} N_{j,t} - \tau_{l,1}(1-\tau_1)\bar{w}_t L_t - \tau_k r_t A_t}{C_t} \quad (20)$$

$$\tau_{l,t} = \frac{G_t + subsidy_t + \Delta D_t - \Upsilon_1 \sum_{j=1}^{J} N_{j,t} - \tau_{c,1}C_t - \tau_k r_t A_t}{(1-\tau_1)\bar{w}_t L_t}. \quad (21)$$

$$\tau_{k,t} = \frac{G_t + subsidy_t + \Delta D_t - \Upsilon_1 \sum_{j=1}^{J} N_{j,t} - \tau_{c,1}C_t - \tau_{l,1}(1-\tau_1)\bar{w}_t L_t}{r_t A_t}. \quad (22)$$

In the baseline scenario we compute the values of $\tau_{c,t}$, $\tau_{l,t}$ or alternatively the values of $\tau_{k,t}$ such that there is no growth of the government debt. The initial calibrated government deficit remains the same for the initial steady state, final steady state and the transition path. Spending on public goods and services are constant in *per capita* terms ($g_t = g_1$). In the reform scenario we pursue the same, having in mind that the welfare effects of the reform will stem from the reform itself and the changes in taxes. The tax closures imply that the costs of the reform are concentrated among the transition cohorts.

Tax progressivity closure In this closure we introduce progressive labor income taxes: low income tax rate and high income tax rate above (relative) income threshold. All earnings below 150% of average labor income are taxed at *low* rate ($\tau_{l,t}^{LI}$), average labor income in each period is $(1-\tau)\bar{w}_t\bar{l}_t$, where $\bar{l}_t$ is average labor supply in period t. On earned income above this threshold we impose tax rate ($\tau_{l,t}^{HI}$). Total gross labor income ($(1-\tau)\bar{w}_t L_t$) is a sum of two components: earnings below threshold (LI) and earnings taxed at higher rate (HI):

$$LI_t = \sum_{j=1}^{\bar{J}} N_{j,t} \int_{\Psi_t} \min(\omega_{j,t}(\psi_{j,t})(1-\tau)\bar{w}_t l_{j,t}(\psi_{j,t}), 1.5(1-\tau)\bar{w}_t\bar{l}_t) dX(\psi_{j,t})$$

$$HI_t = \sum_{j=1}^{\bar{J}} N_{j,t} \int_{\Psi_t} \max(\omega_{j,t}(\psi_{j,t})(1-\tau)\bar{w}_t l_{j,t}(\psi_{j,t}) - 1.5(1-\tau)\bar{w}_t\bar{l}_t), 0) dX(\psi_{j,t})$$

In the initial steady state both tax rates are equal, $\tau_{l,1}^{LI} = \tau_{l,1}^{HI} = \tau_{l,1}$. In the final steady state and transition path in the baseline scenario we assume that $\tau_{l,1}^{HI} = 2 * \tau_{l,1}^{LI}$. The same rule is used in the reform scenario. Therefore cost of introducing the reform is concentrated on agents with high income.

$$\tau_{l,t}^{LI} = \frac{G_t + subsidy_t + \Delta D_t - \Upsilon_1 \sum_{j=1}^{J} N_{j,t} - \tau_{c,1}C_t - \tau_{k,1} r_t A_t - \tau_l^{LI} LI_t}{LI_t + 2HI_t} \quad (23)$$

$$\tau_{l,1}^{HI} = 2 * \tau_{l,1}^{LI} \quad (24)$$

Public debt closure This closure allows part of the costs of the reform to be financed by future generations. To avoid public debt explosion in the model, we assume following fiscal rule:

$$\tau_{tax,t} = (1-\varrho)\tau_{tax}^{final} + \varrho\tau_{tax,t-1} + \varrho_D\left(\left(\frac{D}{Y}\right)_t - \left(\frac{D}{Y}\right)^{final}\right) \forall tax \in l, c \quad (25)$$

where ϱ measures the speed of the adjustment in the tax rate, and ϱ_D the strength of reaction to deviation of government debt from its steady state values. The values of τ_c^{final}, τ_l^{final} and $(D/Y)^{final}$ denote in the new steady state values of consumption tax, labor tax and debt share in GDP, respectively. In the baseline scenario we allow public debt and taxes to adjust to the changing balance of the pension system. In parallel to the tax closures, the same is pursued in the reform scenario, hence the welfare effects will stem from a combination of two factors: changes in the pension benefits and changes in taxes.

Public spending closure In order to balance the pension system, government may reduce the expenditure on public goods and services consumed by the agents. *Per capita* spending g_t is given by:

$$g_t = \frac{1}{\sum_{j=1}^{J} N_{j,t}} \cdot \left(subsidy_t + \Delta D_t - T_t\right). \quad (26)$$

Consequently, there will be direct welfare effects of fiscal policy coupled with the welfare effects of 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 a 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. Note, that while consumers derive direct utility from government expenditure, the general equilibrium effects of this closure are different than when taxes are reduced.

2.3 Measuring welfare effects

The calculation of consumption equivalent for each agent at age j, at time t and in state $\psi_{j,t}$ is based on relationship

$$u^B = u(c_{j,t}^B, l_{j,t}^B, g_t^B) = u((1+\mu)c_{j,t}^R, l_{j,t}^R, g_t^R) = u^R \quad (27)$$

where superscript B refers to the baseline scenario and superscript R to the reform scenario. The instantaneous utility function is defined as in equation (2). Having defined

$\mu = 1 - \exp\left(u^B - u^F\right)$, it may be generalized to lifetime terms as follows:

$$M_{1,t} = 1 - \exp\left(\frac{U^B_{1,t} - U^R_{1,t}}{\sum_{s=0}^{J} \delta^s \frac{\pi_{1+s,t+s}}{\pi_{1,t}}}\right). \tag{28}$$

In this expression, $U_{1,t}$ refers to lifetime utility of the newborn at period t in base and reform scenario over stochastic streams of consumption and labor, respectively.

For each agent we compute 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. Consumption equivalent of each agent is discounted to the age $j = 1$. Computing a consumption equivalent for agents alive in the first, pre-reform period we have take in to account their distribution over state space. Thus for cohort j years old at period 1 we have

$$M_{j,1} = 1 - exp\left(\frac{E(U^B_{j,1}) - E(U^R_{j,1})}{\sum_{s=0}^{J} \delta^s \frac{\pi_{j+s,1+s}}{\pi_{j,1}}}\right) \tag{29}$$

Subsequently, $M_{j,t}$ is expressed in terms of consumption discounted to $j = 1$. Then W total welfare effect of the reform is given by

$$W = \sum_{j=2}^{J}\left(M_{j,1}\sum_{s=1}^{J-j}\prod_{i=2}^{s}\frac{z_i}{r_i}\mathbf{E}(c_{j+s,1+s})\right) + \sum_{t=1}^{\infty}\left(M_{1,t}\sum_{s=1}^{J}\prod_{i=2}^{t-1+s}\frac{z_i}{r_i}\mathbf{E}(c_{s,t-1+s})\right) \tag{30}$$

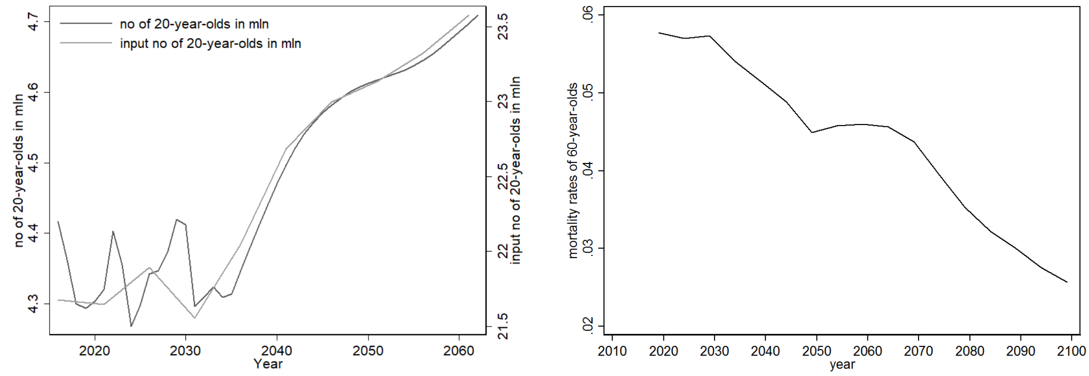
The sum of these equivalents over time is a measure of the welfare effects of the reform in a Hicksian sense: in principle government is able to compensate the losses and still observe a surplus.

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 close to 4%. Depreciation rate d so that the aggregate investment rate matched the one observed in the data, i.e. app. 25%.

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 rate. After periods covered by projection we assume that mortality is constant and that annual population growth rate (n) converges to 1.002 in the final steady state, see Figure 1.

Figure 1: 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

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), but there appears to be a consensus that in the long run the technological progress will converge to values short of 2.0 *per annum*, witch we assume as a constant on whole transition path. Note that higher values of γ are beneficial for the DB system, indexed with payroll growth. Moreover, with a stable technological progress, the main force secular changes in the interest rate is demographics.

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 besed on estimates from Krueger and Ludwig (2013). In our model each period corresponds to 5 years.[5]

Preferences. We calibrate the preference for leisure ϕ such that we replicate the share of hours worked observed in the economy of 33% on the average. The discount factor $\delta = 1.006^5$ value was set to match the interest rate of 4%. We calibrate the preference for government consumption such that in the initial steady state it is optimal (the marginal rate of substitution between private consumption and public expenditure are equal for a given share of hours).

[5]Hence we need to recalculate input variables according $\varrho_\eta = \bar{\varrho}_\eta{}^5$ and $\sigma_\eta = \bar{\sigma}_\eta \frac{1-\bar{\varrho}_\eta{}^5}{1-\bar{\varrho}_\eta}$.

Pension system parameters We set the replacement rate $\rho = 0.215$ to match the 5.2% ratio of pensions to GDP. The effective rate of contribution $\tau = 7.8\%$ 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 τ_k was set to 13%, to match 3.6% share of 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 the rate of revenues from consumption tax (3.8%). The calibration of tax rates is based on the OECD data, details are provided in the Appendices.

The calibration of the model parameters is summarized in Table A3 in the Appendices.

3.1 Baseline scenario

With changes in demography, maintaining *status quo* of baseline PAYG DB pension system requires adjustments in the pension system. The left panel of Figure 2 reports the change in the balance of the pension system, when we employ the fiscal adjustments as policy options. In the initial steady state we assume balanced pension system. Over the analyzed horizon the imbalance 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 the right panel of Figure 2. Indeed, the replacement rate would need to go down by as much as 40% (from roughly 18.3% to below 14%). A smaller magnitude of adjustment would be needed in the contribution rate due to the increasing base (positive population growth).[6] 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.

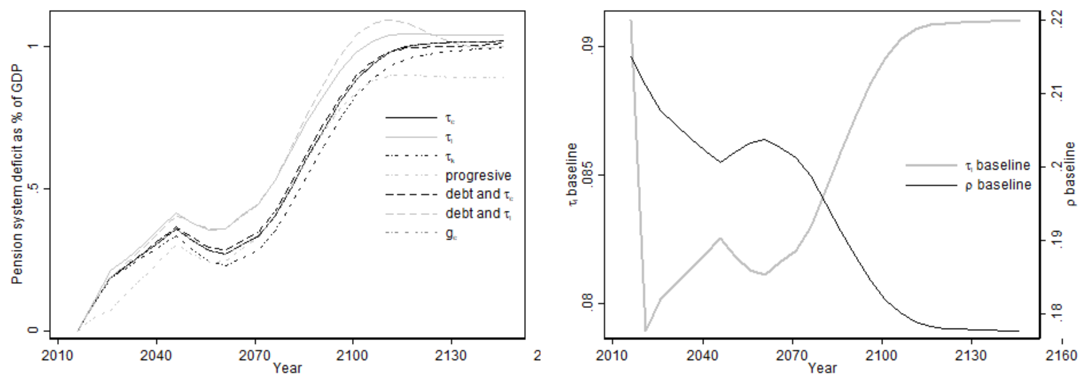
4 Results

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. An often neglected aspect of the reform, however, is the fact that the way the pension system reform is financed generates welfare effects on its own. In this paper we test the validity of the earlier literature findings about the role of the insurance motive

[6] These results are consistent with Fehr (2000), Braun and Joines (2015).

Figure 2: Baseline scenario – the effects of demographics

(a) adjustment in fiscal parameters (b) adjustment in pension parameters



Notes: Figures depict adjustment needed in the tax system to balance the pension system (left) or the adjustment in the pension system to maintain fiscal neutrality (right). The policy options reported follow the menu presented in section 2.2. The policy option denoted as τ_c balances the pension system with a contemporaneous increase in consumption taxation, analogously τ_l stands for adjustment of labor tax and τ_k capital income tax. The policy option denoted as *debt and* τ_c employs the fiscal rule. The policy option denoted as g_t adjusts government expenditure to finance pension system imbalance. The policy option denoted as τ adjusts the contribution rate to maintain pension system balanced. The policy option denoted as ρ adjusts the net replacement rate ($\rho(1 - \tau_b)$) to maintain pension system balanced.

against a variety of fiscal closures used to finance the transition costs of the reform. This way we reconcile results from various studies – some suggesting welfare gains and other welfare losses from the pension system reform, in both deterministic and stochastic setup.

The reform necessitates a relatively high transition cost. In the first period of the reform, the shortage of funds in the social insurance fund grows to roughly 32% of the total balance (from a calibration of zero shortage in the initial steady state). This shortage comes from a number of the offsetting effects. First, strengthening the link between the labor supply and the pension benefits substantially increases the labor supply, which raises the base for the contributions. Second, the wages adjust downwards to the increased labor supply, hence partially offsetting the growth in the contribution base. Third, a part 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. Finally, adjustment in labor generates general equilibrium effects, which also yield adjustment in the balance of the pension system. In the subsequent periods, the transfer to the capital pillar is continued, whereas the adjustment in labor supply are no longer as large. By contrast, longevity raises the costs of the pension benefits from the previous system.

These adjustments imply considerable fiscal adjustments, and subsequently the welfare effects. We portray these welfare effects in terms of a consumption equivalent between the baseline scenario of no change in the pension system and a reform scenario of the systematic change in the pension system which consists of partial privatization and introducing gradually the defined contribution in the place of defined benefit rules. Indeed, if fiscal closure was neutral to the evaluation of the reform, one should expect that both aggregate welfare and between cohort distribution of welfare effects to be similar. It is not the case. For each of the analyzed fiscal closures, we display the consumption equivalent in Table 1. We show both the final steady state and the aggregate welfare effects, integrating the losses and the benefits across generations.

Our comparison reveals stark differences between fiscal closures for the same pension reform, as inferred from comparing the numbers along the diagonal. When fiscal closure is the same in the baseline and in the reform, we isolate the effects of the reform conditional on the fiscal closure. These numbers range from positive to negative, suggesting that indeed the fiscal closure is an important driver of the total welfare effect. The intuition behind these results is as follows. Take the example of labor taxation as a fiscal closure. Agents already benefit from less distortionary environment in defined contribution setup, hence they increase their labor supply in response to the reform. With higher labor supply, labor taxes could be reduced, which further encourages increase in labor supply. By contrast, if reform is to be financed by lower pension benefits of the contemporaneous retirees, there is little reason for adjustment by workers (except for general equilibrium effects from their reduced consumption). The very existence of these effects is intuitive, what we provide in Table 1.

More importantly, the earlier literature hints that the welfare effects of pension system reform become negative in models with idiosyncratic income shocks (e.g. Nishiyama and Smetters 2007). This result does not seem to be general, though. In contrast to the earlier findings we show that for some fiscal closures welfare effects are positive despite idiosyncratic setup. Our simulations show that 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.

There is also typically a fiscal closure for the reform scenario which gains sufficient political support to be democratically chosen. Interestingly, the welfare improving closures are not the same as the politically favored closures. Utilizing the information about the share of the cohorts living in the first steady state and benefiting from the reform, we compute also a measure of political support. 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.[7] Figure 4 is 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 rate 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 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 A5 in the Appendix. The increase ranges between 6.5% and 9.1% relative to the baseline scenario, depending on the distortion introduced by the fiscal adjustment (notably, in the baseline scenario).[8] Indeed, in the baseline scenario adjustment in pension

[7]For the cohorts living already 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.

[8]Note, that this economy experiences a population growth, which implies that the labor supply

system parameters necessitated by fiscal neutrality is substantial, recall Figure 2b with a substantial increase in the contributions rate. In the reform scenario, the contribution rate declines by as much as 3 p.p relative to the initial steady state and 4 p.p. relative to the baseline, see Figure A1. 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 initial old (see Figure 4a), as opposed to the reduction in pension benefits (see Figure 4b). Moreover, while in 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.

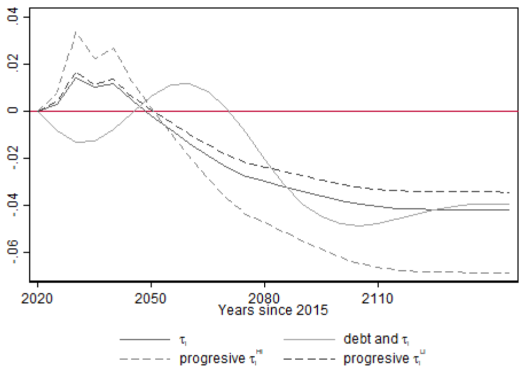
Among the non-neutral closures, in the aggregate terms there appears to be substantial reduction in welfare for many fiscal adjustments. There is also a clear divide between adjustments which tax labor and others. This is theoretically founded and intuitive. Pension system reform allows for better alignment in the labor supply incentives between macro and micro-levels, reducing the scope for labor supply distortions. However, individual productivity risk become more afflicting. This trade off has been at the core of many earlier studies (e.g. Heer 2015), but it appears that in the long run, the the effects associated with lower distortion to the labor supply distortion dominate the effects associated with the idiosyncratic income shocks: welfare improves in the final steady state regardless of the fiscal closure. The long run effect varies between 0.2% and 0.7% of the lifetime income in terms of consumption equivalent.

The interesting observation is that if agents are able to reduce labor taxation sufficiently smoothly – the combination of labor taxation and public debt – welfare gains are possible, while no such outcome is observed for consumption taxation. The rationale behind this result is similar to the findings concerning the fiscally neutral adjustment in the contribution rates. Reform strengthens the link between labor supply and pensions, thus providing incentives to work more. Ability to adjust labor taxes downwards by a more than proportional increase in labor supply reinforces this mechanism, rendering reforms coupled with labor taxation more welfare improving than reforms coupled with alternative fiscal arrangements. This is confirmed with the analysis of adjustment in taxes, see Figure 3. Although in the long run, due to the reform, pension system allows for taxes to decline, in the scenarios financed by consumption taxation this decline is delayed. Situation is easier on consumers if consumption taxation is smoothened by public debt, but still in such scenarios labor taxation is held constant throughout the

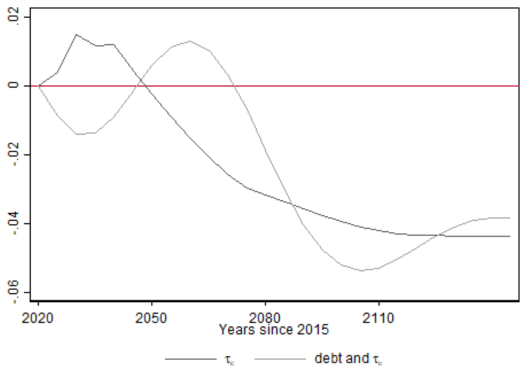
increases irrespectively of the reform.

entire simulation scenario. Hence, while labor taxation scenarios reinforce the initial boost for the labor supply from the reform, consumption taxation scenarios do not.

Figure 3: Labor income and consumption tax (p.p. difference between reform and baseline scenario)



(a) τ_l - labor income



(b) τ_c - consumption

Our 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). For example, the setup of Imrohoroglu et al. (2003)[9] 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 intuition for why Imrohoroglu et al. (2003) find large, negative effects in 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.

[9]We relate closer to Imrohoroglu et al. (2003) than to Nishiyama and Smetters (2003, 2007) because the latter analyze a different reform. However, the comparison of the mechanics is similar with reference to both studies.

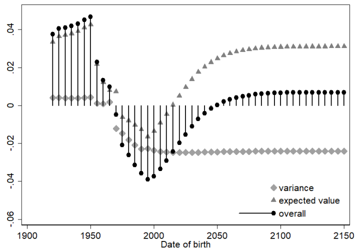
Our results are also partly counter-intuitive. Typically, one would expect consumption taxes to yield welfare gains in the reform scenario.Consumption taxes, in contrast to labor taxes, are neutral intra-temporally: gross consumption and labor supply are uninfluenced. However inter-temporal choice is affected. *Per capita* public spending, even if presents in utility function, is absent from MRS. As a consequence g is neutral intra-temporally as well as inter-temporally and yields to even less distortion. However, this reasoning only applies to cases where reform necessitates upward adjustment in taxation. The link between labor supply and pension benefits, implicit in the defined contribution pension system, appears to provide very strong reaction by the households. While working more is not welcome in principle, immediate reduction in taxation due to the reform is sufficient to cause a substantial increase in taxable labor supply, thus financing the introduction of the funded pillar.

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 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 being welfare improving. This result comes from the fact that generations living at the time of reform only partially experience change in pension system and nearly all of them benefit from the accompanying fiscal adjustments, see Figure 4. The exception of course is reduction in pension benefits – despite providing sound welfare gains in the long run and overall, it is never politically favored.

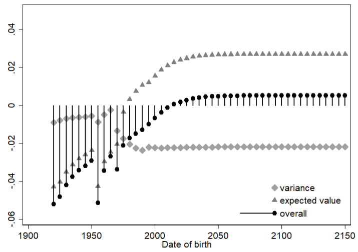
Given our results, one is forced to go deeper on two issues: incentives for labor supply implicit in the reformed pension system and the reduction in the insurance motive insurance implicit in baseline pension system. Can one reasonably expect adjustment in labor supply so large that taxation may decline despite (temporarily) increased fiscal imbalance? Admittedly, reform immediately reduces labor taxation by virtually 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% – seems plausible in the light of the model. However, is a stronger link between pension contributions and pension benefits sufficient to cause such strong adjustments in the real world? 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

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

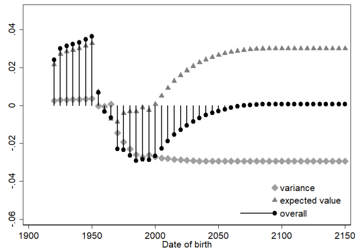
(a) τ - contribution rate



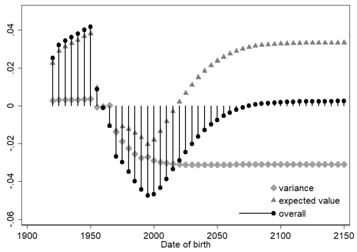
(b) τ_b - pension benefits



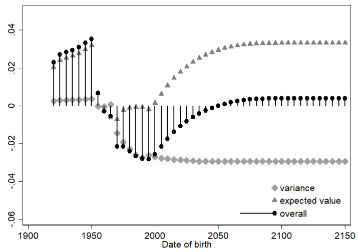
(c) g_t - public expenditure



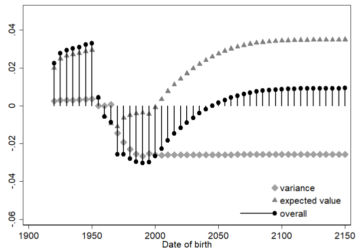
(d) τ_l - labor tax



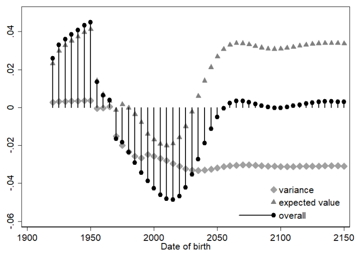
(e) τ_c - consumption tax



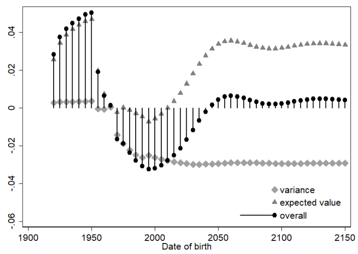
(f) τ_k - capital tax



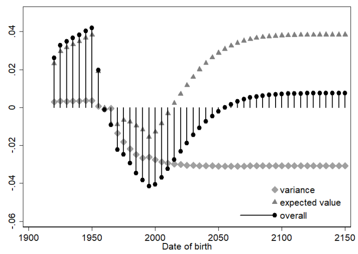
(g) debt τ_l - public debt



(h) debt τ_c - public debt



(i) progression



and roughly 0.1 for the extensive margin (e.g. Keane and Rogerson 2012, Chetty 2012).[10] Such would be consistent with our outcomes. However, this is conditional on workers internalizing the entire adjustment in their decision process. Here 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 second issue concerns the insurance motive. One of the ways to address this

[10] 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.

question is to analyze the same economy and the same reform in a deterministic setting. These results are reported in Table A6. 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 A4). We find many similarities between the stochastic and the deterministic model, though admittedly the welfare effects are much larger in the deterministic model, hinting a large role for the insurance motive *per se*. Notwithstanding, many results return: 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 is much more options with political support. The reason is revealed by Figure A2, which compares the cohort patterns of the welfare effects for the stochastic model and both deterministic models (with analogous calibration and recalibrated). Indeed, cohort patterns are quite similar – the main difference is the level of consumption equivalent, much higher in the deterministic scenarios. Notably, recalibration matters only in selected cases, mostly for the public expenditure closure, which owes much to the change of the initial steady state parameters.

5 Conclusions

This paper addressed the welfare effects of various fiscal closures when switching from a defined benefit pay-as-you-go system to a partially funded defined contribution system. While the efficiency of such types of reform has already been addressed in the literature, there is a considerable variation in the fiscal closures adopted in previous studies. This paper aims at comparing the welfare effects of the reform *depending* on the fiscal closure. We systematize the policy options utilized in earlier literature, by analyzing them in a controlled environment of one single reform in one single economy. We also extend the policy options to comprise additional instruments on the side of government in the context of longevity.

Our findings reveal that the fiscal closure itself can change the evaluation of the reform – from negative to positive. Moreover, the long-run effects too may depend on the policy option used by the government to finance the reform or use the finances released by the changes in the pension system. The effects of the accompanying fiscal policy are not only large, but also provide for differentiated distributions of the welfare effects across cohorts. Hence, they matter for the political support both at the implementation stage of the pension system reform and its stability.

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. This suggests that a number of reforms which were not as efficiency enhancing in previous works could be more beneficial if coupled with a proper fiscal closure closure. Second, 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. Third, we show that although the insurance motive has a large bearing on the size of the welfare effects, especially in the long run, qualitatively the conclusions are fairly similar between stochastic and deterministic scenarios.

Table 1: Welfare effects of the pension system reform

Fiscal closure	Baseline								
	τ	pensions	τ_c	τ_l	τ_k	$\tau_l^{LI,HI}$	$debt\tau_c$	$debt\tau_l$	g_t
	Welfare effects – final steady state								
Reform τ	0.70	0.53	0.52	0.52	0.44	1.02	0.52	0.52	0.55
Reform pensions (τ_b)	0.70	0.53	0.52	0.52	0.44	1.02	0.52	0.52	0.55
Reform τ_c	0.63	0.48	0.39	0.39	0.41	0.89	0.39	0.39	0.42
Reform τ_l	0.55	0.42	0.25	0.24	0.31	0.75	0.25	0.24	0.27
Reform τ_k	1.07	0.84	1.00	1.00	0.93	1.50	1.00	1.00	1.03
Reform progression ($\tau_l^{LI,HI}$)	0.51	0.35	0.26	0.26	0.34	0.76	0.26	0.26	1.04
Reform $debt\tau_c$	0.63	0.48	0.39	0.39	0.41	0.89	0.39	0.39	0.42
Reform $debt\tau_l$	0.55	0.42	0.25	0.24	0.31	0.75	0.25	0.24	0.27
Reform g_t	0.48	0.38	0.05	0.04	0.12	0.55	0.05	0.04	0.08
	Welfare effects – aggregate								
Reform τ	0.07	0.13	-0.04	-0.03	-0.15	0.53	-0.05	-0.02	0.02
Reform pensions (τ_b)	0.06	0.11	-0.06	-0.05	-0.17	0.51	-0.06	-0.04	0.00
Reform τ_c	0.09	0.15	-0.06	-0.05	-0.16	0.51	-0.06	-0.05	0.00
Reform τ_l	-0.12	-0.04	-0.38	-0.37	-0.43	0.18	-0.38	-0.37	-0.32
Reform τ_k	0.57	0.48	0.64	0.64	0.55	1.17	0.63	0.64	0.68
Reform progression ($\tau_l^{LI,HI}$)	-0.23	-0.18	-0.43	-0.42	-0.48	0.13	-0.43	-0.42	-0.19
Reform $debt\tau_c$	0.07	0.13	-0.08	-0.07	-0.18	0.49	-0.09	-0.07	-0.02
Reform $debt\tau_l$	-0.11	-0.04	-0.38	-0.37	-0.43	0.19	-0.38	-0.37	-0.32
Reform g_t	-0.04	0.07	-0.39	-0.38	-0.49	0.19	-0.40	-0.38	-0.33
	Political majority (% of voters approving the reform - 50%)								
Reform τ	8	16	8	8	8	16	8	8	8
Reform pensions (τ_b)	-50	-50	-50	-50	-50	-50	-50	-50	-50
Reform τ_c	-7	0	-7	0	-7	8	-7	8	-7
Reform τ_l	-7	0	-7	-7	-7	8	-7	-7	-7
Reform τ_k	-7	0	-7	-7	-7	8	-7	-7	-7
Reform progression ($\tau_l^{LI,HI}$)	-7	-7	-15	-7	-15	-7	-7	-7	-7
Reform $debt\tau_c$	0	8	0	8	0	8	8	8	8
Reform $debt\tau_l$	8	8	0	8	0	8	8	8	0
Reform g_t	-7	0	-7	-7	-7	8	-7	0	-7

Note: Results report aggregate welfare effects for all cohorts, equation (30). Political support 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 (19). Closure τ_b refers to situation when pension benefits are reduced to ensure pension system balance, see equation (19). Closures τ_c, τ_l and τ_k stand for immediate adjustment of consumption, labor and capital income tax respectively, compare with equations (20), (21) and (22). Tax progressivity closure is indicated as *progression*, see equations (23) - (24). Closures *debt* τ_c and *debt* τ_l permit to use public debt to temporarily fund the costs of the pension system reform, with fiscal rule described in equation (25). The public spending closure (g_t) follows equation (26).

References

Aglietta, M., Chateau, J., Fayolle, J., Juillard, M., Le Cacheux, J., Le Garrec, G. and Touzé, V.: 2007, Pension reforms in Europe: An investigation with a computable OLG world model, *Economic Modelling* **24**(3), 481–505.

Andolfatto, D. and Gervais, M.: 2008, Endogenous debt constraints in a life-cycle model with an application to social security, *Journal of Economic Dynamics and Control* **32**(12), 3745–3759.

Auerbach, A. and Kotlikoff, L. J.: 1987, *Dynamic Fiscal Policy*, Cambridge University Press.

Bagchi, S.: 2015, Labor supply and the optimality of social security, *Journal of Economic Dynamics and Control* **58**, 167–185.

Bassi, M.: 2008, An Egg Today and a Chicken Tomorrow: A Model of Social Security with Quasi-Hyperbolic Discounting, *CSEF Working Paper 205*, Centre for Studies in Economics and Finance (CSEF), University of Naples, Italy.

Belan, P. and Pestieau, P.: 1999, Privatizing social security: A critical assessment, *The Geneva Papers on Risk and Insurance Issues and Practice* **24**(1), 114–130.

Boersch-Supan, A. H. and Ludwig, A.: 2010, Old Europe ages: Reforms and Reform Backlashes, *NBER Working Paper 15744*, National Bureau of Economic Research.

Börsch-Supan, A., Härtl, K. and Ludwig, A.: 2014, Aging in europe: Reforms, international diversification, and behavioral reactions, *American Economic Review* **104**(5), 224–229.

Bouzahzah, M., De la Croix, D. and Docquier, F.: 2002, Policy reforms and growth in computable OLG economies, *Journal of Economic Dynamics and Control* **26**(12), 2093–2113.

Braun, A. and Joines, D. H.: 2015, The implications of a graying japan for government policy, *Journal of Economic Dynamics and Control* **57**, 1 – 23.

Bruce, N. and Turnovsky, S. J.: 2013, Social security, growth, and welfare in overlapping generations economies with or without annuities, *Journal of Public Economics* **101**, 12–24.

Caliendo, F. N., Guo, N. L. and Hosseini, R.: 2014, Social security is not a substitute for annuity markets, *Review of Economic Dynamics* **17**(4), 739–755.

Chen, D. H., Beetsma, R. M., Ponds, E. H. and Romp, W. E.: 2016, Intergenerational risk-sharing through funded pensions and public debt, *Journal of Pension Economics and Finance* **15**(02), 127–159.

Chetty, R.: 2012, Bounds on elasticities with optimization frictions: A synthesis of micro and macro evidence on labor supply, *Econometrica* **80**(3), 969–1018.

Chetty, R., Friedman, J. N., Olsen, T. and Pistaferri, L.: 2011, Adjustment costs, firm responses, and micro vs. macro labor supply elasticities: Evidence from danish tax records, *Quarterly Journal of Economics* **126**(2), 749–804.

Cipriani, G. P. and Makris, M.: 2012, PAYG pensions and human capital accumulation: some unpleasant arithmetic, *The Manchester School* **80**(4), 429–446.

Davidoff, T., Brown, J. R. and Diamond, P. A.: 2005, Annuities and individual welfare, *American Economic Review* **95**(5), 1573–1590.

De la Croix, D., Pierrard, O. and Sneessens, H. R.: 2012, Aging and pensions in general equilibrium: Labor market imperfections matter, *Journal of Economic Dynamics and Control* **37**(1), 104–124.

Diamond, P.: 2004, Social security [dagger], *American Economic Review* **94**(1), 1.

Diamond, P., Kashin, K., King, G. and Soneji, S.: 2016, Correspondence: Scoring social security proposals, *Journal of Economic Perspectives* **30**(2), 245–247.

Díaz-Giménez, J. and Díaz-Saavedra, J.: 2009, Delaying retirement in Spain, *Review of Economic Dynamics* **12**(1), 147–167.

Fehr, H.: 2000, Pension reform during the demographic transition, *The Scandinavian Journal of Economics* **102**(3), 419–443.

Fehr, H.: 2009, Computable stochastic equilibrium models and their use in pension-and ageing research, *De Economist* **157**(4), 359–416.

Fehr, H.: 2016, CGE modeling social security reforms, *Journal of Policy Modeling* **38**(3), 475 – 494.

Fehr, H., Habermann, C. and Kindermann, F.: 2008, Social security with rational and hyperbolic consumers, *Review of Economic Dynamics* **11**(4), 884–903.

Fehr, H. and Kindermann, F.: 2010, Pension funding and individual accounts in economies with life-cyclers and myopes, *CESifo Economic Studies* **56**(3), 404–443.

Fernald, J. G. and Jones, C. I.: 2014, The future of US economic growth, *American Economic Review* **104**(5), 44–49.

Galasso, V.: 1999, The U.S. Social Security System: What Does Political Sustainability Imply?, *Review of Economic Dynamics* **2**(3), 698–730.

Genakoplos, J., Mitchell, O. S. and Zeldes, S. P.: 2000, Would a Privatized Social Security System Really Pay a Higher Rate of Return, *Technical Report 6713*, National Bureau of Economic Research.

Gordon, R. J.: 2014, The demise of u.s. economic growth: Restatement, rebuttal, and reflections, *Working Paper 19895*, National Bureau of Economic Research.

Harenberg, D. and Ludwig, A.: 2015, Social security in an analytically tractable overlapping generations model with aggregate and idiosyncratic risks, *International Tax and Public Finance* **22**(4), 579–603.

Harenberg, D. and Ludwig, A.: 2016, Idiosyncratic risk, aggregate risk, and the welfare effects of social security, *SAFE Working Paper 59*, University of Frankfurt.

Heer, B.: 2015, Optimal pensions in aging economies, *CESifo Working Paper Series No. 5192* .

Heer, B. and Irmen, A.: 2014, Population, pensions, and endogenous economic growth, *Journal of Economic Dynamics and Control* **46**, 50 – 72.

Huggett, M. and Ventura, G.: 1999, On the Distributional Effects of Social Security Reform, *Review of Economic Dynamics* **2**(3), 498–531.

Imrohoroglu, A., Imrohoroglu, S. and Joines, D. H.: 2003, Time-Inconsistent Preferences and Social Security, *The Quarterly Journal of Economics* **118**(2), 745–784.

Keane, M. and Rogerson, R.: 2012, Micro and macro labor supply elasticities: A reassessment of conventional wisdom, *Journal of Economic Literature* **50**(2), 464–476.

Keuschnigg, C., Davoine, T. and Schuster, P.: 2012, Aging and pension reform, a general equilibrium approach, *Background paper for the ECA Old-Age Insurance report - Final report*, European Comission.

Kindermann, F. and Krueger, D.: 2014, High Marginal Tax Rates on the Top 1%? Lessons from a Life Cycle Model with Idiosyncratic Income Risk, *NBER Working Paper 20601*, National Bureau of Economic Research, Inc.

Kitao, S.: 2014, Sustainable social security: Four options, *Review of Economic Dynamics* **17**(4), 756–779.

Kitao, S.: 2015, Pension reform and individual retirement accounts in Japan, *Journal of the Japanese and International Economies* **38**, 111–126.

Kotlikoff, L. J., Smetters, K. and Walliser, J.: 1999, Privatizing Social Security in the U.S. – Comparing the Options, *Review of Economic Dynamics* **2**(3), 532–574.

Krueger, D. and Kubler, F.: 2003, Pareto Improving Social Security Reform when Financial Markets are Incomplete?, *National Bureau of Economic Research Working Paper Series* **No. 9410**.

Krueger, D. and Ludwig, A.: 2013, Optimal progressive labor income taxation and education subsidies when education decisions and intergenerational transfers are endogenous, *American Economic Review* **103**(3), 496–501.

Kuhle, W.: 2010, The Optimum Structure for Government Debt, *MEA discussion paper series 09194*, Mannheim Research Institute for the Economics of Aging (MEA), University of Mannheim.

Kumru, C. S. and Piggott, J.: 2010, Should Public Retirement Pensions Be Means-tested?, *DEGIT Conference Papers*, number 049, DEGIT, Dynamics, Economic Growth, and International Trade.

Kumru, C. S. and Thanopoulos, A. C.: 2011, Social security reform with self-control preferences, *Journal of Public Economics* **95**(7-8), 886–899.

Lindbeck, A. and Persson, M.: 2003, The gains from pension reform, *Journal of Economic Literature* **41**(1), 74–112.

Ludwig, A. and Vogel, E.: 2009, Mortality, Fertility, Education and Capital Accumulation in a Simple OLG Economy, *MEA discussion paper series*, Mannheim Research Institute for the Economics of Aging (MEA), University of Mannheim.

Makarski, K., Hagemejer, J. and Tyrowicz, J.: 2017, Efficiency of the pension reform: the welfare effects of various fiscal closures, *Macroeconomic Dynamics* **forthcoming**.

McGrattan, E. and Prescott, E.: 2017, On financing retirement with an aging population, *Quantitative Economics* **8**, 75–115.

Nishiyama, S. and Smetters, K.: 2003, Consumption Taxes and Economic Efficiency in a Stochastic OLG Economy, *Working Paper 9492*, National Bureau of Economic Research.

Nishiyama, S. and Smetters, K.: 2007, Does Social Security Privatization Produce Efficiency Gains?, *The Quarterly Journal of Economics* **122**, 1677–1719.

Okamoto, A.: 2005, Simulating progressive expenditure taxation in an aging Japan, *Journal of Policy Modeling* **27**(3), 309–325.

Roberts, M. A.: 2013, Pareto-improving pension reform through technological implementation, *Scottish Journal of Political Economy* **60**(3), 317–342.

Sanchez-Marcos, V. and Sanchez-Martin, A. R.: 2006, Can social security be welfare improving when there is demographic uncertainty?, *Journal of Economic Dynamics and Control* **30**(9), 1615–1646.

Song, Z., Storesletten, K., Wang, Y. and Zilibotti, F.: 2015, Sharing high growth across generations: pensions and demographic transition in china, *American Economic Journal: Macroeconomics* **7**(2), 1–39.

Verbič, M.: 2007, Varying the parameters of the Slovenian pension system: an analysis with an overlapping-generations general equilibrium model, *Post-communist economies* **19**(4), 449–470.

Verbič, M., Majcen, B. and Van Nieuwkoop, R.: 2006, Sustainability of the Slovenian pension system: an analysis with an overlapping-generations general equilibrium model, *Eastern European Economics* **44**(4), 60–81.

Vogel, E., Ludwig, A. and Boersch-Supan, A.: 2012, Aging and pension reform: extending the retirement age and human capital formation, *Working Paper Series 1476*, European Central Bank.

Wright, R., Mérette, M. and Lisenkova, K.: 2012, The Impact of Population Ageing on the Labour Market: Evidence from Overlapping Generations Computable General Equilibrium (OLG-CGE) Model of Scotland, *Mimeo*.

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
Krueger and Kubler (2003)	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
Vogel et al. (2012)	aging	p	$\tau_I, \tau_b, \bar{J}$			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

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 Model calibration

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

Notes: We calibrate taxes share in GDP as 5 years average.

Table A4: 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
ϕ_g	preference for public consumption	0.263	0.027
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	0.276
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	0.650
ϱ_D	strength of debt-tax link	0.300	0.300

C Results for the main macroeconomic indicators

Table A5: Macroeconomic effects

Macroeconomic indicators	Fiscal closure for baseline and reform								
	τ	pension (τ_b)	τ_c	τ_l	τ_k	progression	$debt\tau_c$	$debt\tau_l$	g_t
	Final steady state relative to the initial steady state value (baseline scenario)								
aggregate labor [a]	167	167	167	164	167	167	167	167	166
aggregate K/L [a]	14.70	14.72	14.70	14.79	14.80	14.72	14.70	14.97	14.58
interest rate [b]	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
	Change in aggregate labor in reform scenario as a % deviation from baseline								
2020	6.40	6.58	7.44	7.81	6.90	8.09	7.92	8.03	7.44
2040	7.25	7.27	8.50	8.19	8.41	8.23	8.30	8.40	8.50
2060	7.79	7.34	9.03	9.10	8.81	9.41	8.70	7.90	9.03
$+\infty$	7.55	6.96	9.06	9.11	8.50	9.80	9.06	9.10	9.06
	Change in aggregate capital in reform scenario as a % deviation from baseline								
2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2040	7.45	10.22	10.70	9.42	9.35	8.91	8.14	9.92	10.70
2060	12.69	14.16	16.70	15.99	17.60	15.52	14.97	14.79	16.70
$+\infty$	18.65	14.86	19.36	23.96	27.63	23.92	19.36	23.96	19.36
	Change in (annual) interest rate in reform scenario in p.p. deviation from baseline								
2020	0.22	0.22	0.25	0.27	0.23	0.27	0.27	0.27	0.25
2040	-0.01	-0.09	-0.07	-0.04	-0.03	-0.06	0.03	-0.05	-0.07
2060	-0.15	-0.20	-0.22	-0.20	-0.24	-0.21	-0.17	-0.20	-0.22
$+\infty$	-0.30	-0.22	-0.28	-0.39	-0.49	-0.39	-0.36	-0.39	-0.28

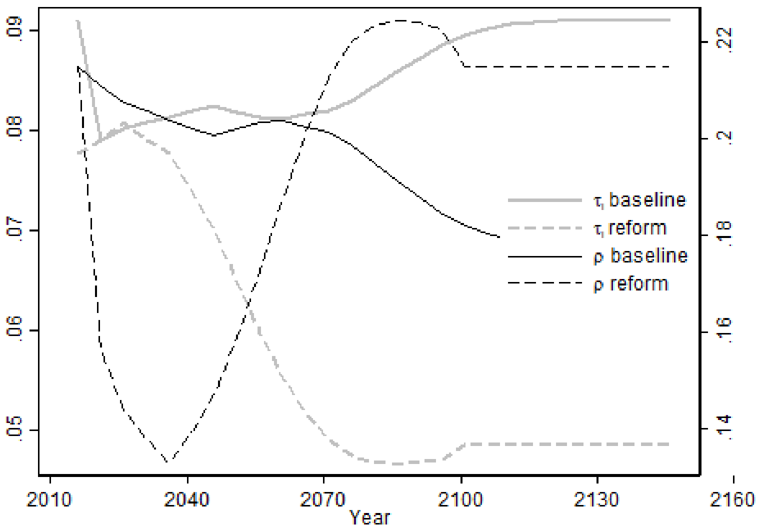
Note: Results report aggregate labor and capital as a % change between reform and baseline, when the same fiscal closure is assumed in both baseline and reform scenarios, equivalent to the diagonal of Table 1. Calibration presented in Table A3.

[a] – expressed in % of the initial steady state

[b] – expressed in pp. difference to initial steady state

Closure τ denotes the situation in which contribution rate is adjusting to make the pension system fiscally neutral, as in equation (19). Closure *pension* (τ_b) refers to reduction in pension benefits to assure pension system balance, see equation (19). Closures τ_c, τ_l and τ_k stand for immediate adjustment of consumption, labor and capital income tax respectively, see with equations (20) and (21). Tax progressivity closure is indicated as *progression*, see equations (23) - (24). Closures *debt* τ_c and *debt* τ_l permit to use public debt as a resource of financed pension system reform. To avoid public debt explosion fiscal rule described in the equation (25) is applied. The adjustment via public spending (g_t) following equation (26).

Figure A1: Adjustments of the pension system's parameters in the baseline and the reform scenario



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

D Deterministic model

Table A6: Welfare effects for deterministic model, original calibration

Fiscal closure	Baseline τ	τ_b	τ_c	τ_l	τ_k	$debt\tau_c$	$debt\tau_l$	g_t
	Welfare effects – final steady state							
Reform τ	2.82	2.70	2.62	2.63	3.57	2.62	2.63	2.89
Reform pensions (τ_b)	2.82	2.70	2.62	2.63	3.37	2.62	2.63	2.89
Reform τ_c	3.18	3.02	3.11	3.11	3.60	3.11	3.11	3.37
Reform τ_l	3.14	2.99	3.05	3.05	3.61	3.05	3.05	3.31
Reform τ_k	2.54	2.54	3.02	2.97	3.52	3.02	2.97	0.05
Reform $debt\tau_c$	3.18	3.02	3.11	3.11	3.60	3.11	3.11	3.37
Reform $debt\tau_l$	3.14	2.99	3.05	3.05	3.61	3.05	3.05	3.31
Reform g_t	0.99	1.08	0.13	0.14	3.86	0.13	0.14	0.40
	Welfare effects – aggregate							
Reform τ	2.06	2.07	1.89	1.92	2.81	1.89	1.92	2.41
Reform pensions (τ_b)	2.08	2.09	1.91	1.93	2.74	1.91	1.94	2.42
Reform τ_c	2.43	2.41	2.40	2.42	2.92	2.40	2.43	2.91
Reform τ_l	2.25	2.24	2.14	2.17	2.94	2.14	2.17	2.64
Reform τ_k	1.73	1.75	2.26	1.99	2.80	2.23	1.99	-0.19
Reform $debt\tau_c$	2.41	2.40	2.37	2.40	2.92	2.37	2.41	2.89
Reform $debt\tau_l$	2.25	2.25	2.14	2.17	2.94	2.14	2.18	2.64
Reform g_t	0.77	0.87	-0.04	-0.02	3.37	-0.05	-0.01	0.49
	Political majority (% of voters approving the reform - 50%)							
Reform τ	41	49	41	49	33	41	49	49
Reform pensions (τ_b)	-17	-17	-17	-17	20	-17	-17	-17
Reform τ_c	41	20	26	41	26	41	49	49
Reform τ_l	41	20	9	33	41	33	41	41
Reform τ_k	41	-17	26	9	26	41	41	17
Reform $debt\tau_c$	49	20	41	49	33	49	49	49
Reform $debt\tau_l$	49	20	41	49	41	49	49	49
Reform g_t	41	20	17	41	41	33	49	49

Note: In a deterministic model all agents are equal within cohort, hence no progressive taxation applies. Results report aggregate welfare effects for all cohorts, equation (30). Political support 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 (19). Closure τ_b refers to situation when pension benefits are reduced to ensure pension system balance, see equation (19). Closures Closures τ_c, τ_l and τ_k stand for immediate adjustment of consumption, labor and capital income tax respectively, compare with equations (20), (21) and (22). Closures *debt* τ_c and *debt* τ_l permit to use public debt to temporarily fund the costs of the pension system reform, with fiscal rule described in equation (25). The public spending closure (g_t) follows equation (26).

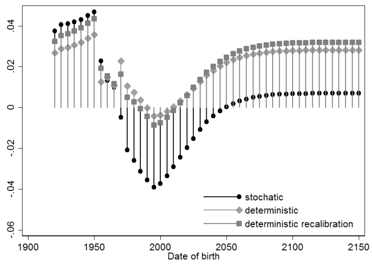
Table A7: Welfare effects for deterministic model, recalibrated economy

	Fiscal closure	Baseline							
		τ	τ_b	τ_c	τ_l	τ_k	$debt\tau_c$	$debt\tau_l$	g_t
		Welfare effects – final steady state							
Reform	τ	3.20	2.86	2.78	2.78	4.16	2.78	2.78	2.80
	pensions (τ_b)	3.20	2.86	2.78	2.78	3.61	2.78	2.78	2.80
	τ_c	3.71	3.25	3.56	3.56	4.16	3.56	3.56	3.59
	τ_l	3.60	3.17	3.36	3.37	4.16	3.36	3.37	3.39
	τ_k	2.77	2.77	3.55	3.36	4.16	3.55	3.36	-1.02
	$debt\tau_c$	3.71	3.25	3.56	3.56	4.16	3.56	3.56	3.59
	$debt\tau_l$	3.60	3.17	3.36	3.37	4.16	3.36	3.37	3.39
	g_t	0.80	1.07	-1.01	-1.01	4.19	-1.01	-1.01	-0.98
		Welfare effects – aggregate							
Reform	τ	2.41	2.34	2.05	2.06	3.48	2.06	2.07	2.35
	pensions (τ_b)	2.44	2.37	2.08	2.09	3.11	2.08	2.10	2.38
	τ_c	2.94	2.76	2.87	2.88	3.67	2.88	2.90	3.17
	τ_l	2.70	2.55	2.50	2.51	3.67	2.51	2.52	2.76
	τ_k	1.96	1.99	2.79	2.42	3.61	2.76	2.43	-1.20
	$debt\tau_c$	2.92	2.74	2.84	2.85	3.67	2.85	2.87	3.15
	$debt\tau_l$	2.72	2.57	2.51	2.52	3.67	2.51	2.53	2.77
	g_t	0.63	1.01	-1.11	-1.10	3.84	-1.10	-1.09	-0.79
		Political majority (% of voters approving the reform - 50%)							
Reform	τ	32	41	24	32	25	32	41	49
	pensions (τ_b)	-25	-17	-25	-17	49	-25	-17	-17
	τ_c	41	49	41	49	25	49	49	49
	τ_l	25	41	-7	0	49	0	8	25
	τ_k	24	-25	41	-7	25	49	41	-7
	$debt\tau_c$	49	49	49	49	41	49	49	49
	$debt\tau_l$	49	49	41	49	49	49	49	49
	g_t	49	49	-7	0	49	0	16	32

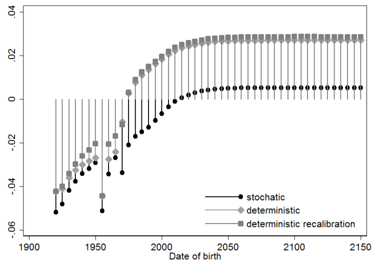
Note: In a deterministic model all agents are equal within cohort, hence no progressive taxation applies. Calibration reported in Table A4. Results report aggregate welfare effects for all cohorts, equation (30). Political support computed as a fraction of cohorts living in the first year (steady state) 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 (19). Closure τ_b refers to situation when pension benefits are reduced to ensure pension system balance, see equation (19). Closures τ_c and tau_l stand for immediate adjustment of consumption and labor tax respectively, compare with equations (20) and (21). Closures *debt* τ_c and *debt* τ_l permit to use public debt to temporarily fund the costs of the pension system reform, with fiscal rule described in equation (25). The public spending closure (g_t) follows equation (26).

Figure A2: Consumption equivalents – comparison between stochastic and deterministic models (% of permanent consumption in reform scenario)

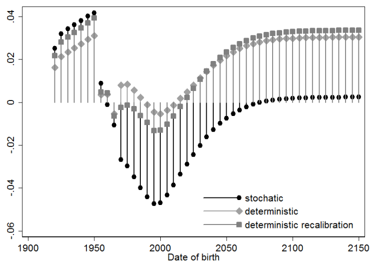
(a) τ - contribution rate



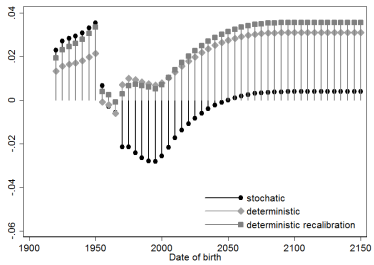
(b) τ_b - pension benefits



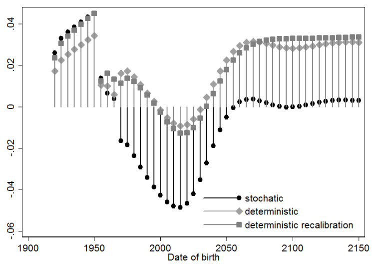
(c) τ_l - labor tax



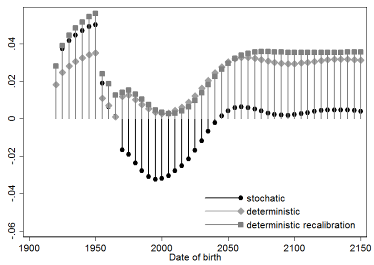
(d) τ_c - consumption tax



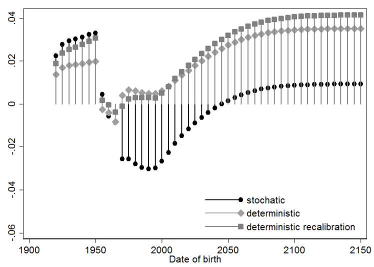
(e) debt τ_l - public debt



(f) debt τ_c - public debt



(g) τ_k - capital income tax



(h) g_t - public expenditure

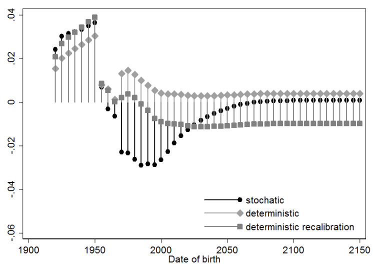


Figure A3: Consumption tax (p.p difference between reform and baseline scenario)