Welfare effects of fiscal policy in reforming the pension system*

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Abstract

Most reforms of the pension systems imply substantial adjustments in between cohort and within cohort redistribution. Fiscal policy, which accompanies these changes may counteract or reinforce this redistribution. In an OLG model with uncertainty we show that fiscal closure is crucial for determining the welfare effects of the pension system reforms as well as political support for introducing it. We analyze two sets of fiscal adjustments: fiscally neutral adjustments in the pension system (via contribution rate or replacement rate) and pension system balanced by a combination of taxes and public debt. We find that adjustments which yield aggregate welfare gains are not likely to obtain political support and vice versa.

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 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 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; 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

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

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 at least partially 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 $\pi_{j+1,t+1}/\pi_{j,t}$.

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

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

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 $r_t = (1 - \tau_k)\bar{r}_t$

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

$$V(\psi_{j,t}) = \max_{c_{j,t}, l_{j,t}, a_{j+1,t+1}} u(c_{j,t}, l_{j,t}, g_t) + \delta \frac{\pi_{j+1,t+1}}{\pi_{j,t}} \mathbf{E}\big(V(\psi_{j+1,t+1}) \mid \psi_{j,t}\big) \tag{2}$$

subject to the budget constraint given by (3) as well as $0 \leqslant c_{j,t}$, $0 \leqslant l_{j,t} \leqslant 1$.

Budget constraint The agent's income is composed of the net labor earnings $w_{j,t} = (1 - \tau_{l,t})(1 - \tau_t)\omega_{j,t}\bar{w}_t$.[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,

[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

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:

$$a_{j+1,t+1} + (1+\tau_{c,t})c_{j,t} + \Upsilon_t = w_{j,t}l_{j,t} + b_{j,t} + (1+r_t)\,a_{j,t} + \Gamma_{j,t}. \tag{3}$$

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:

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

where r^I_t is the payroll growth rate. The total contributions collected in period t are given by $\tau_t \bar{w}_t L_t$. Hence, the budget constraint of the pension system is given by

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

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: $\tau_t = \tau^I_t + \tau^{II}_t$, where we denote by τ^I_t the obligatory contribution that goes into the DC PAYG pillar and by τ^{II}_t 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 $\tau^I_t = 0.67\tau_t$ and $\tau^{II}_t = 0.33\tau_t$.

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:

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

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

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:

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

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

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.

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.

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

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

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

[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.

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* (2)
- ***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***

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

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

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

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

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

- ***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 $f_{j,t}^{I}$ and $f_{j,t}^{II}$ 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 two taxes – on labor or on consumption – adjusts immediately in each period to balance the pension system. It implies

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

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

In the baseline scenario we compute the values of $\tau_{c,t}$ or alternatively the values of $\tau_{t,t}$ 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, $\tau_{l,1}^{LI} = \tau_{l,1}^{HI} = \tau_{l,1}$. As a consequence of the reform, general tax burden will decline. Hence, in order to use progressive labor income tax rate as fiscal closure, we need to allow low income tax rate to adjust downwards. To this end we adopt the following fiscal rule. If balancing government budget described by (12) requires revenues of the labor income tax, the increase in low tax rate is attenuated and the bulk of adjustment is pushed to the high income tax rate:

$$\tau_{l,t}^{LI} = 0.1\tau_{l,t-1}^{LI} + 0.9\tau_{l,1}^{LI} \quad (22)$$

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

Otherwise, we follow the opposite rule, i.e. adjust only low tax rate.

$$\tau_{l,t}^{LI} = \frac{G_t + subsidy_t + \Delta D_t - \Upsilon_1 \sum_{j=1}^{J} N_{j,t} - \tau_{c,1} C_t - \tau_{k,1} r_t A_t - \tau_{l,t}^{HI} HI_t}{LI_t} \quad (24)$$

In fact, tn the baseline scenario, increasing life time expectancy and population growth will result in decreasing tax rates relative to the initial steady state, hence only equation (**??**) apply. In the reform scenario, tax progressivity closure concentrates burden of pension system reform on high income workers. Therefore, it offers a substitute of the social insurance from the negative productivity shock implicit in the DB system.

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:

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

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:

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

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

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

where superscript B refers to the baseline scenario and superscript R to the reform scenario. The instantaneous utility function is defined as in equation (1). Having defined $\mu = 1 - \exp\left(u^B - u^F\right)$, it may be generalized to lifetime terms as follows:

$$M_{1,t} = 1 - \exp\left(\frac{U_{1,t}^B - U_{1,t}^R}{\sum_{s=0}^{J} \delta^s \frac{\pi_{1+s,t+s}}{\pi 1,t}}\right). \tag{28}$$

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.

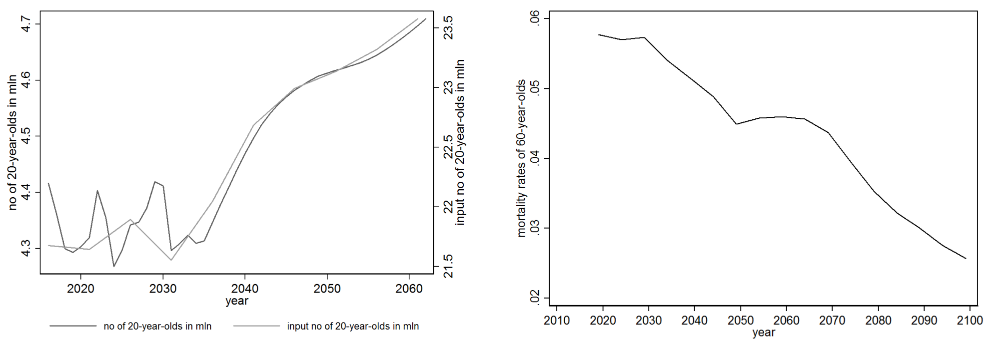
3 Calibration and baseline

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 constant mortality and yearly population growth rate (n) converge to 1.002 in the final steady state, see Figure 1.

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.

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 idiosyncratic 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).

Pension system parameters We set 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 $\bar{J} = 9$.

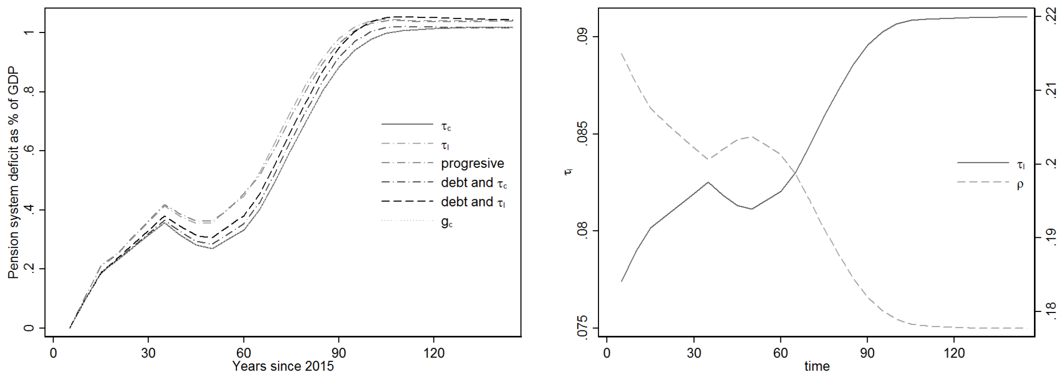
Taxes. The capital income tax τ_k was set to 13%, to match 3.6% share of capital income tax revenues in GDP. The marginal tax rates on labor and consumption were set to 15% and 6.5%. It matches the rate of labor income tax revenues in GDP (9.2%) and the rate of revenues from consumption tax (3.8%). Taxes calibration 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.

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

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. 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.

3.1 Baseline scenario

With changes in demography, maintaining *status quo* of baseline PAYG DB pension system implies 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.

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

4 Results

We our results consist of two substantive parts. First, we portray the welfare effects (and implied political support) of the reform. The baseline scenario PAYG DB system is compared to a gradual introduction to the partially funded DC system. 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. In fact, the differences are stark. Second, we provide explanation for these results analyzing the behavior of the aggregate variables in the economy.

Table 1 summarizes the welfare effects for each fiscal closure for the final steady state comparisons and aggregate comparisons relative to the baseline scenario of no pension system reform. 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. 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.

Earlier literature argued in favor of pension system reform as modeled in our paper, but welfare effects become negative in models with idiosyncratic income shocks (Nishiyama and Smetters, 2007). This result does not seem to be general, though. Our simulations show that regardless of the starting point (fiscal closure in the baseline scenario), there is always a fiscal closure for the reform scenario which yields welfare gains form reform. There is also always a fiscal closure for the reform scenario which gains sufficient political support to be democratically chosen. However the welfare improving closures are not identical to politically favored closures.

Pension system reform allows for better labor supply incentives , however individual productivity risk become more afflicting. As long recognized in the literature (**?**), there appears to be a trade off between the decreased labor supply distortion and the cost from increased labor market risk. In the long run, however, the effects associated with 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 overall effect varies between 0.02% and 3.5% of the lifetime income in terms of consumption equivalent. The largest effects in the final steady state are observed in the public spending closure, because there is virtually zero general equilibrium effects whereas savings in the pension system yield additional government spending which provides direct utility gain to the agents. Overall, the majority of the final steady state welfare effects fall into the range of roughly 0.3-0.7% of the lifetime income which.

Fiscal adjustments have crucial impact on distribution of transition cost and thus overall welfare effect. With the same reform, we observe both positive and negative welfare effects, depending on the fiscal closure, Table 1. In fact, with taxes on labor income – linear or progressive – the welfare effects are negative, even if the adjustment in taxes are smoothed over cohorts with the use of public debt. In the reform scenario link between labor supply an future benefits is clear for all agents. In consequence labor supply increases significantly. Higher labor income tax counteracts this effect, reducing the gains from lowering the overall distortion in the economy.

By contrast, in general, consumption taxes yield welfare gains in the reform scenario, irrespective of the fiscal closure in the baseline. The only exception from this rule is when government

Table 1: Welfare effects

Fiscal closure		Baseline							
		τ	τ_b	τ_c	τ_l	progression	$debt\tau_c$	$debt\tau_l$	g_t
		Welfare effects – final steady state							
Reform	τ	**0.73%**	0.54%	0.54%	0.51%	0.54%	0.54%	0.54%	0.35%
	τ_b	0.73%	**0.67%**	0.54%	0.54%	0.54%	0.54%	0.54%	0.35%
	τ_c	0.78%	0.71%	**0.58%**	0.58%	0.59%	0.12%	0.58%	0.40%
	τ_l	0.55%	0.54%	0.21%	**0.21%**	0.22%	0.21%	0.21%	0.02%
	progression	0.56%	0.55%	0.22%	0.23%	**0.24%**	0.22%	0.23%	0.30%
	$debt\tau_c$	0.78%	0.71%	0.10%	0.13%	0.59%	**0.58%**	0.28%	0.40%
	$debt\tau_l$	0.55%	0.54%	0.21%	0.29%	0.22%	0.21%	**0.21%**	0.02%
	g_t	2.82%	2.34%	3.52%	3.53%	3.53%	3.52%	3.53%	**3.34%**
		Welfare effects – aggregate							
Reform	τ	**0.12%**	0.28%	-0.09%	0.01%	0.02%	-0.02%	0.16%	-0.30%
	τ_b	0.06%	**0.22%**	-0.02%	-0.05%	-0.04%	-0.09%	0.09%	-0.36%
	τ_c	0.24%	0.38%	**0.12%**	0.15%	0.16%	0.12%	0.30%	-0.15%
	τ_l	-0.12%	0.08%	-0.46%	**-0.40%**	-0.39%	-0.43%	-0.28%	-0.68 %
	progression	-0.08%	0.12%	-0.42%	-0.39%	**-0.38%**	-0.42%	-0.27%	-0.20%
	$debt\tau_c$	0.22%	0.36%	0.10%	0.13%	0.15%	**0.12%**	0.28%	-0.17%
	$debt\tau_l$	0.06%	0.22%	-0.31%	0.29%	-0.8%	-0.13%	**-0.16%**	-0.57%
	g_t	1.87%	1.69%	2.63%	2.66%	2.67%	2.63%	2.81%	**2.36%**
		Political support							
Reform	τ_I	**58.13%**	66.12%	58.13%	66.12%	66.12%	66.12%	66.12%	58.13%
	τ_b	0.00%	**0.00%**	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	τ_c	37.13%	55.94%	**37.13%**	52.66%	52.66%	44.80%	55.94%	37.13%
	τ_l	44.80%	44.80%	37.13%	**44.80%**	44.80%	37.13%	44.80%	37.13%
	progression	37.13%	44.80%	37.13%	37.13%	**44.80%**	37.13%	44.80%	48.08%
	$debt\tau_c$	44.80%	55.94%	48.1%	55.94%	55.94%	**55.94%**	55.94%	48.08%
	$debt\tau_l$	52.66%	55.94%	37.13%	52.66%	52.66%	44.80%	**52.66%**	37.13%
	g_t	29.69%	44.80%	37.13%	44.40%	52.66%	44.80%	52.66%	**37.13%**

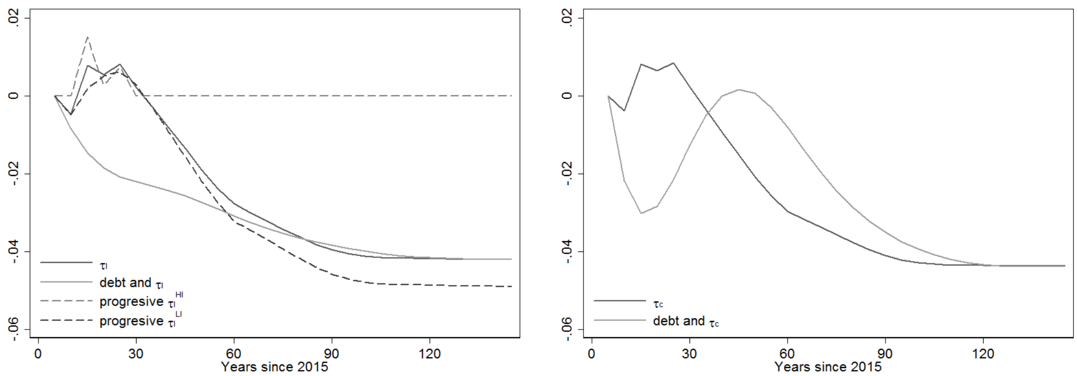
Note: Results report aggregate welfare effects for all cohorts, equation (30). Political support computed as a fraction of cohorts living in the first year (steady state) benefiting from the reform. Closure τ denotes the situation in which contribution rate is adjusting to make the pension system fiscally neutral, as in equation (19). Closure τ_b refers to position when tax on pension benefit is imposed 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). Tax progressivity closure is indicated as *progression*, see equations (22) - (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 last column (g_t) is the public spending closure, as in the equation (26).

expenditure adjusts in the baseline scenario. Adjustment $\tau_{c,t}$ brings less distortion. 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.

Note that pure adjustment in consumption taxes is not politically favored, but if smoothed with public debt, it becomes a viable policy alternative. However, fiscal closures with debt adjustment are treacherous. It is easy to have political support for welfare deteriorating reform if debt may rise during transition ($\tau_c \rightarrow debt\tau_l$, $progression \rightarrow debt\tau_l$, $debt\tau_l \rightarrow debt\tau_l$).

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

(a) τ_l - labor income (b) τ_c - consumption



Above comparison gives important policy implications. First, pension system reform financed by consumption tax almost ensure positive welfare effects, opposite is true for labor income taxes. Second, enable public deficit adjustment would not change welfare effect of beneficial politic, besides, it may ensure political support (debt τ_c).

Although the reform is introduced gradually, there is never political support to finance the reform through the reduction in pension benefits, although such adjustment could yield welfare improvement. This is because such policy option immediately adjusts downward current DB pension benefits and further reduces already low DC pension benefits for the transition cohorts. Admittedly, the long run welfare gains are the highest for for fiscally neutral reforms in the pension system. Also, unlike downward adjustment in pensions, the upward adjustment in pension contributions can gain political support, because it concentrates losses among the youngest among the cohorts living and working at the time of the reform, which is too small of a population fraction to prevent this reform. Possibly, if adjustment in contributions was smoothed by an adjustment in public debt, the overall positive welfare effect of the reform could even be higher.

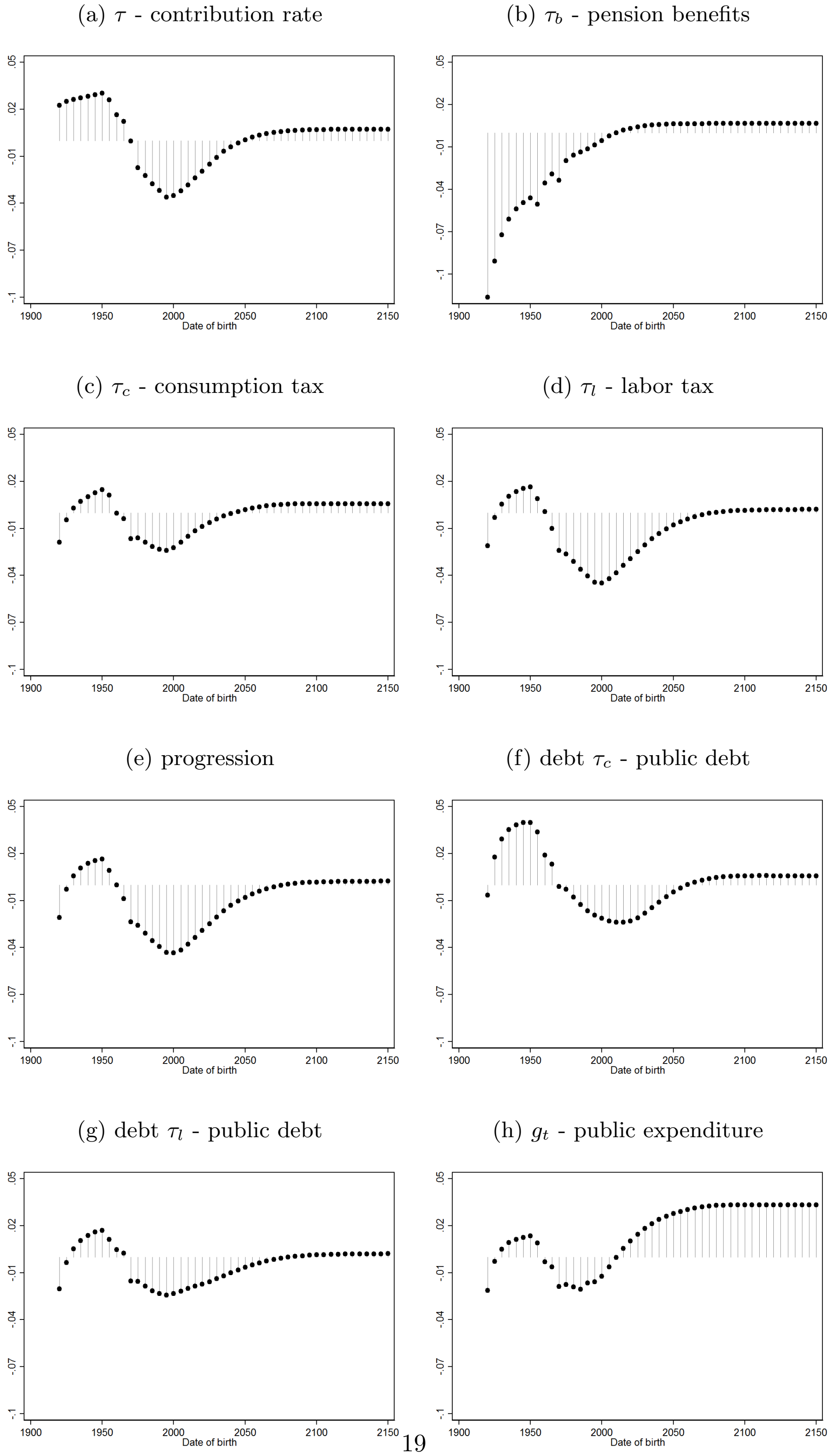
5 Conclusions

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 may matter for the political support both at the implementation stage of the pension system reform and its stability.

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



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A Literature

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 (2008)	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 (2013) 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 goods and services	0.412	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.

C Results for the main macroeconomic indicators

Table A4: Macroeconomic effects

Macroeconomic indicators	Fiscal closure for baseline and reform							
	τ	τ_b	τ_c	τ_l	progression	$debt\tau_c$	$debt\tau_l$	g_t
	Aggregate Labor							
2020	6.50%	6.5%	1 7.41%	7.98%	7.79%	8.04%	7.12%	7.41%
2040	7.23%	7.27%	8.50%	8.18%	8.15%	8.41%	8.52%	8.50%
2060	7.76%	7.34%	9.03%	9.07%	8.81%	8.68%	9.02%	9.03%
$+\infty$	7.55%	6.96%	9.05%	9.10%	8.50%	9.05%	9.10%	9.05%
	Aggregate Capital							
2020	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2040	7.90%	10.27%	10.76%	10.07%	10.20%	7.38%	11.00%	10.76%
2060	12.86%	14.17%	16.70%	16.26%	16.14%	12.86%	18.24%	16.70%
$+\infty$	18.65%	14.86%	19.36%	23.96%	23.16%	19.36%	23.96%	19.36%
	Interest rate (yearly)							
2020	0.0022	0.0022	0.0025	0.0027	0.0027	0.0027	0.0024	0.0025
2040	-0.0002	-0.0009	-0.0007	-0.0006	-0.0006	0.0003	-0.0007	-0.0007
2060	-0.0015	-0.0020	-0.0022	-0.0020	-0.0021	-0.0012	-0.0026	-0.0022
$+\infty$	-0.0003	-0.0022	-0.0028	-0.0039	-0.0039	-0.0028	-0.0039	-0.0028

Note: Results report aggregate labor and capital as a percentage change between reform and baseline. Interest rate present change in percentage point. 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 position when tax on pension benefit is imposed 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). Tax progressivity closure is indicated as *progression*, see equations (22) - (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 last column (g_t) is the public spending closure, as in the equation (26).