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ANALYZING THE EFFICIENCY OF PENSION REFORM: THE ROLE OF THE WELFARE EFFECTS OF FISCAL CLOSURES

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Replacing the pay-as-you-go defined benefit (PAYG DB) system with an at least partially funded defined contribution (DC) system generates fiscal costs that need financing. The fiscal closures at hand differ by the channel and the extent of distortions. The main contribution of this paper is a thorough comparison of the welfare effects of the various fiscal closures of the pension system reform. In addition, we decompose the welfare effects to the parts attributable to changing the way pensions are financed (PAYG $\Rightarrow$ prefunding) and to changing the way pensions are computed (DB $\Rightarrow$ DC). We show that depending on the fiscal closure, the welfare effects differ substantially for the same pension system reform. The financing of the the pension system gap with public debt allows more intergenerational redistribution.

Keywords: Pay as You Go, Pension System Reform, Time Inconsistency, Welfare

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1. INTRODUCTION AND MOTIVATION

With increasing longevity and decreasing fertility rates, maintaining pay-as-you-go defined benefit (PAYG DB) schemes in their current form is becoming fiscally (and socially) nonviable in many economies. The majority of numerical exercises demonstrate that fiscal balance requires a substantial decrease in retirement benefits or an equally substantial increase in contribution rates.[1] The alternative consists of a systemic reform imposing so-called (partially) prefunded defined contribution (DC) schemes that translate longevity into an automatic reduction in effective replacement rates. This path was followed by some of the Central and Eastern European countries, as well as Sweden, among others. Such reforms are often referred to as privatization of pension systems; see Diamond (1993).

A large part of the literature finds that a privatization of social security is efficient, although the extent of the 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)] and market imperfections [Nishiyama and Smetters (2007); De la Croix et al. (2013)].[2] Such reforms imply two main sources of fiscal adjustments. First, a reform changes (future) pension payouts by changing the effective replacement rates. This directly affects the situation of the (future) retirees, but also indirectly affects the situation of those who contribute to the pension system in the future, which may not be the same cohorts. Second, a shift of contributions from a pay-as-you-go (PAYG) to an (at least partially) funded system leaves a fiscal gap. Pensions of the cohorts whose contributions were sent to PAYG DB, but who retire after DC is introduced, generate a public expenditure that requires financing. Direct taxation of labor or consumption in this context may be substituted by allowing the public debt to accumulate, thus yielding future taxation (of labor or consumption). If taxes are distortionary, spreading the costs of reform over many generations may actually induce lower welfare loss than concentrating the distortion among only a few working cohorts.[3] On the other hand, any debt needs to be serviced, ushering in the financial costs of reform. Which of the two is a dominant factor remains an open question.

If the choice of the fiscal closure affects the welfare outcome of the reform, the assumption about the fiscal closure may have an important bearing on whether a reform is welfare-enhancing. The multiplicity of solutions raises a methodological question about the efficiency of the reform. In fact, it follows that under one fiscal closure, pension system reforms may actually be Pareto-improving, whereas under another this would no longer the case. Interestingly enough, the impact of fiscal closures is usually left out of analysis in the literature. On the other hand, the literature is quite inconsistent about the type of fiscal closure used. Nishiyama and Smetters (2007) and Okamoto (2005b) use a lump-sum tax, and Auerbach and Kotlikoff (1987) adjust the contribution rates, whereas Fehr et al. (2008); Keuschnigg et al. (2012); Fehr and Kindermann (2010) and Ludwig and Vogel (2009) employ tax and contribution rate adjustments interchangeably, just to mention a few. Oddly enough, a solution very widely employed by governments—raising public debt—has rarely been analyzed.[4] As noted already by Kotlikoff et al. (1999), fiscal closures have welfare effects on their own, i.e., consequences in addition to direct ones driven by changes in pension systems. Yet, despite their paramount policy relevance, the role of the fiscal closures—to the best of our knowledge—has not been analyzed previously in the literature.[5] Thus, we contribute to the literature by quantifying and comparing the macroeconomic and welfare effects of a single pension reform under various fiscal closures. We put these indirect welfare costs in the perspective of total effects of a pension reform.

We rely on an overlapping-generations (OLG) model, in the spirit of the seminal contribution of Auerbach and Kotlikoff (1987). The originally fairly constrained model has subsequently been extended in a number of relevant directions.[6] Modern models are equipped with a demographic transition, as deteriorating demographics has been demonstrated to be the driving factor for changes in the fiscal stance; see De Nardi et al. (1999) and Fehr (2000).[7] In addition to demographics, modern models also conceptualize the welfare effects of reform in addition to the changes in macroeconomic aggregates. The analysis comprises change in utility observed across cohorts along the entire transition path, as pioneered by Breyer (1989) and Feldstein (1995).

We construct an experiment in which welfare effects of a pension system reform are computed for a variety of fiscal closures: (i) lump-sum contemporaneous taxation; (ii) labor and consumption (contemporaneous) taxation; and (iii) public debt complemented (if needed) by contemporaneous taxation. To avoid the criticism of Holzman and Stiglitz (2001), our results report measures of welfare for living and future cohorts. To compare the overall aggregates for various fiscal closures, we utilize a mechanism of a lump-sum redistribution authority (LSRA), following Nishiyama and Smetters (2007).[8] Another important advantage of the model is the explicit treatment of the demographic issues: both fertility and mortality rates are dynamic in our model, following the official demographic projection.

In designing and calibrating the model, we follow closely the features of a reform implemented by one of the countries that actually undertook pension system reform from a PAYG DB system to a partially prefunded DC system—Poland. Thanks to this choice, we avoid the risk of a hypothetical design of the reform, as has been customary in the literature. Yet Poland is a catching-up and quickly aging economy, which may limit the general character of our findings. Thus, we complement the scenario that follows the data-driven projections with a scenario with lower technological progress already in the initial steady state and more favorable demographics. In this way, although the reform is actual, the economy is more similar to the frequently analyzed cases of advanced economies.[9]

The pension reform in Poland was implemented in 1999. The original system was a DB PAYG scheme. The reform kept the contribution rates constant, but substantially changed the way the pensions were computed. Both of the new compulsory pillars were constructed as defined contribution schemes. After the reform, the first pillar is still a PAYG, but the contributions are recorded in individual accounts in the Social Insurance Fund (SIF) and will serve as a basis for computing an annuity upon retirement—a system referred to as notionally defined contribution (NDC). The contributions in that pillar are indexed annually according to payroll growth. The second pillar is a fully funded DC scheme, where open pension funds (OPFs) invest contributions in the name of participants in a financial market with returns exempt from the capital income tax. Neither the contributions nor the interest on savings can be claimed prior to retirement. Both pillars are mandatory.[10] This reform creates an inevitable fiscal gap in the first pillar, SIF. The Polish constitution imposes a debt ceiling of 60% debt-to-GDP ratio. If this ceiling is exceeded, the government is obliged to run a balanced budget and reduce the debt. At the moment of the reform, the debt share in GDP was equal to 45% of GDP, whereas the contemporaneous annual SIF was 0.8% of GDP.

Given this design of the reform, our model needs to replicate the PAYG DB initial steady state and the baseline path with this pension system, as well as a second path with an unexpected change to a NDC complemented with a funded DC in period 2 of the reform scenario. We replicate the size of the pension system and the split between NDC and the funded DC component and obey the debt limit imposed by the constitution in our fiscal adjustment.

Our contribution to the literature is twofold. First, we explicitly differentiate between fiscal closures to compare welfare effects of the pension reform. Indeed, the fiscal closure can matter by as much as 20–30% of the overall welfare effect (expressed in terms of an average over the analyzed fiscal closures). Second, we decompose the welfare effects of the pension system reform into a component attributable to the change from DB to DC and a part attributable to the establishment of the prefunded pillar. We find that the majority of the welfare effects come from a DB $\rightarrow$ DC change and a subsequent decrease in pensions. The economy at the moment of reform still had fairly favorable demographics and relatively high productivity growth. They both deteriorate over time, which makes the baseline scenario of no policy change interesting per se. To test how robust our results are, we complement this scenario of productivity and demographics with one where productivity growth is slower and demographics more favorable to the PAYG DB system. As an additional robustness check, we test if the conclusions are susceptible to the time inconsistency in the preferences. The results prove robust to these modifications.

The paper is structured as follows. The theoretical model is presented in Section 2, whereas Section 3 describes calibration and simulation scenarios in detail. We present the results and various sensitivity checks in Section 4. The final sections conclude by emphasizing the policy recommendations emerging from this study.

2. THEORETICAL MODEL

We use a general equilibrium OLG model in the spirit of Huang et al. (1997), cast in a framework of exogenous but time-varying growth. Bouzahzah et al.

(2002), as well as Zhang and Zhang (2009), discuss the sensitivity of OLG models to assumptions concerning growth in the light of policy reforms and show that when pension systems are analyzed, there is little or no effect of endogenizing productivity growth.

2.1. Population Dynamics

Agents live for $j = 1, 2 \ldots, J$ periods and are heterogeneous with respect to age j, but homogeneous within each cohort. Consumers are born at age 20, which we denote as $j = 1$ to simplify the problem of labor market entry timing as well as educational choices. Consumers face age- and time-specific survival rates $\pi_{j,t}$, which is period-t unconditional survival probability up to age j. At all points in time, consumers who survive until age $J = 80$ die with certainty. The share of the population surviving until older ages is increasing, to reflect changes in longevity. Decreasing fertility is operationalized by a falling number of births. The data for mortality and births come from a demographic projection until 2060 and are subsequently treated as stationary until the final steady state.[11] In each period t, agents at the age $j = \bar{J}_t$ are forced to retire.[12]

Agents have no bequest motive, but because survival rates $\pi_{j,t}$ are lower than one, in each period t a certain fraction of cohort j leave unintentional bequests, which are distributed within the cohort.

2.2. Preferences and Endowments

At each point in time t, an individual of age j born at time $t - j$ consumes a non-negative quantity of a composite good $c_{j,t}$ and allocates $l_{j,t}$ time to work (total time endowment is normalized to one). Consumers can accumulate voluntary savings $s_{j,t}$ that earn the interest rate r_t. Consumers' lifetime utility is as follows:

$$U_j(c_{j,t}, l_{j,t}) = u_j(c_{j,t}, 1 - l_{j,t}) + \beta \sum_{s=1}^{J-j} \delta^s \frac{\pi_{j+s,t+s}}{\pi_{j,t}} u_j \left(c_{j+s,t+s}, 1 - l_{j+s,t+s}\right), \tag{1}$$

where β denotes time inconsistency in the form of quasi-hyperbolic discounting,[13] whereas discounting takes into account time preference δ and probability of survival. There is no risk in the model.[14] The instantaneous utility function is given by $u_j(c_{j,t}, l_{j,t}) = c_{j,t}^{\phi}(1 - l_{j,t})^{1-\phi}$, and we assume that $l_{j,t} = 0$ for $j \geq \bar{J}_t$. In this specification, ϕ determines steady state labor supply. The agent of age j in period t maximizes her utility function $u_j(c_{j,t}, l_{j,t})$ subject to the sequence of budget constraints (see Appendix).

Agents in the transition period are endowed with so-called initial capital; see Section 3.

2.3. Production

Individuals supply labor (time) to the firms, and their productivity varies with age. The amount of effective labor of age j used at time t by a production firm is $L_t = \sum_{j=0}^{\bar{J}_t} \omega_j l_{j,t}$, where ω_j is the age-specific productivity.[15] Using capital and labor, the producers provide a composite consumption good with the Cobb–Douglas production function $Y_t = K_t^{\alpha}(z_t L_t)^{1-\alpha}$, which features labor-augmenting exogenous technological progress, denoted as $\gamma_t = z_{t+1}/z_t$. The standard maximization problem of the firm yields the return on capital $r_t^k = \alpha K_t^{\alpha-1}(z_t L_t)^{1-\alpha} - d$ and the real wage $w_t = (1-\alpha)K_t^{\alpha} z_t^{1-\alpha} L_t^{-\alpha}$, where d denotes the depreciation rate on capital.

2.4. Interest Rate

The interest rate r in our economy is a net rate of return from investing in a composite asset, which consists of government bonds and a capital asset. The return on the capital asset is given by FOC. We assume that the interest rate on government bonds is lower than that on capital assets, $r^G = \xi r^k$ with $\xi < 1$; otherwise the government would be forced to finance debt at a prohibitively high cost. Households purchase a portfolio consisting of capital assets and government bonds, where the share of the latter is determined by the volume of government debt, $r = \mu r^k + (1-\mu)r^G$, where μ is implied by the share of public debt in the savings portfolio. In a world with no risk and no risk preference—as is the case in our setting—households would invest in assets offering a higher return, thus setting μ at unity. In order to avoid this, we assume that households choose a volume of savings at the composite rate r rather than the composition of a portfolio. The share of government expenditure in savings is determined exogenously by the supply of government bonds.

2.5. Pension System

The prereform (baseline) pension system is a PAYG DB system, with an exogenous contribution rate τ and an exogenous replacement rate ρ with $b_{\bar{J},t} = \rho \cdot w_t \cdot \omega_{\bar{J}} \cdot l_{\bar{J}}$ holding $\forall t$.[16] The benefits are indexed annually to 25% of the payroll growth rate denoted by r^I, $b_{j,t} = (1 + 0.25 r_t^I) b_{j-1,t-1}$. The system collects contributions from the workers and pays benefits to the retirees,

$$\sum_{j=\bar{J}_t}^{J} \pi_{j,t} N_{t-j} b_{1,j,t} = \tau_{1,t} \sum_{j=1}^{\bar{J}_t - 1} w_{j,t} \pi_{j,t} N_{t-j} l_{j,t} + \text{subsidy}_t, \tag{2}$$

where subsidy_t is a subsidy/transfer from the government to balance the pension system and $w_{j,t} = \omega_j w_t$.

The postreform pension system is a DC with two pillars: a PAYG NDC and a funded DC. The DC-funded pillar of the pension system collects contributions as an individual stock of (mandatory) pension savings and at retirement converts them to an annuity. The NDC pillar of the system collects the contributions and uses them to cover contemporaneous benefits, but pays out an pensions computed on the basis of accumulated contributions, as given by equation (3). For simplicity, we denote by τ_1 the obligatory contribution that goes into the DC PAYG system and by τ_2 the mandatory contribution that goes into the funded system, with $\tau = \tau_1 + \tau_2$, whereas b_1 and b_2 denote benefits from these two components of the pension system, with $b = b_1 + b_2$. Under a defined contribution pension system, benefits in the two pillars at retirement age are computed according to the following formulas:

$$b_{1,\bar{J}_t,t} = \frac{\sum_{s=1}^{\bar{J}_t-1}\left[\Pi_{\iota=1}^{s}(1+r^{I}_{t-j+\iota-1})\right]\tau_{t-j+s-1}w_{s,t-j+s-1}l_{s,t-j+s-1}}{\prod_{s=\bar{J}}^{J}\pi_{s,t}},$$
$$b_{2,\bar{J}_t,t} = \frac{\sum_{s=1}^{\bar{J}_t-1}\left[\Pi_{\iota=1}^{s}(1+r^{II}_{t-j+\iota-1})\right]\tau_{2,t-j+s-1}w_{s,t-j+s-1}l_{s,t-j+s-1}}{\prod_{s=\bar{J}}^{J}\pi_{s,t}}, \quad \textbf{(3)}$$

where $r_t^{II} = r_t$. Afterward, pensions are indexed to 25% of the payroll growth in the first pillar, $b_{1,j,t} = (1+0.25r_t^I)b_{1,j-1,t-1}$, and to the interest rate in the second pillar, $b_{2,j,t} = (1+r_t)b_{2,j-1,t-1}$. Agents see no direct link between contributions and pensions—in the utility function the derivative of pension benefits w.r.t. to labor supply is zero in both pension systems.

2.6. The Government

Labor income tax $\tau_{l,t}$ and social security contributions $\tau_{\iota,t}$ are deducted from gross income $\omega_j w_t l_{j,t}$ to yield disposable labor income. Interest earned on savings r_t is taxed with $\tau_{k,t}$. In addition, there is a consumption tax $\tau_{c,t}$ as well as a lump-sum tax/transfer Υ_t equal for all generations, which we use to set the budget deficit in accordance with the data. The government collects taxes and spends a fixed share of GDP on unproductive yet necessary consumption $G_t = \gamma * Y_t$. Government balances the pension system. Given that the government is indebted, it naturally also services the outstanding debt:

$$T_t = \tau_{l,t}\left(w_t L_t + \sum_{j=\bar{J}_t}^{J} b_{j,t}\pi_{j,t}N_{t-j}\right) + \left(\tau_{c,t}c_t + \tau_{k,t}r_t s_{j,t-1}\right)\sum_{j=1}^{J}\pi_{j,t}N_{t-j}, \quad \textbf{(4)}$$

$$G_t + \text{subsidy}_t + r_t^G D_{t-1} = T_t + (D_t - D_{t-1}) + \Upsilon_t \sum_{j=1}^{J}\pi_{j,t}N_{t-j}. \quad \textbf{(5)}$$

We set initial steady state debt D_t at the initial data level, and final steady state at around 45% of GDP, which was the actual value of the debt-to-GDP ratio in 1999. We calibrate Υ_t in the steady state to match the deficits and debt to keep long-run debt-to-GDP ratio fixed throughout the whole path. The overall debt-to-GDP ratio is not allowed to exceed 60% in the model, which is the constitutional limit in Poland. Once this threshold is hit, labor or consumption tax immediately adjusts (depending on the selected closure; details discussed later).

2.7. Measuring Welfare Gains.

The utility of a $j-$aged agent in period t is defined as in equation (A.1) in the Appendix. We denote allocation and welfare in the baseline scenario (no reform) with the superscript B and in the reform scenario with the superscript R. Then the consumption equivalent of the reform is computed according to the formula

$$U_{1,t}\left(\tilde{c}_t^B, \tilde{l}_t^B\right) = U_{1,t}\left((1+\mu_t)\tilde{c}_t^R, \tilde{l}_t^R\right), \tag{6}$$

where $\tilde{c}_t = (c_{1,t}, c_{2,t+1}, \dots, c_{J,t+J-1})$ and $\tilde{l}_t = (l_{j,1}, l_{j+1,2}, \dots, l_{J,J-j+1})$. A negative value of μ_t informs us that the reform is welfare-improving for the cohort born in period t. Consumption equivalent is expressed as a measure of compensating variation, i.e., how much the consumer would have to be compensated for the lack of the reform (as a percentage of permanent postreform consumption). For the j-aged agent alive at the reform date $t = 1$ we compute it analogously,

$$U_{j,1}\left(\tilde{c}_{j,1}^B, \tilde{l}_{j,1}^B\right) = U_{j,1}\left[(1+\mu_{1,j})\tilde{c}_{j,1}^R, \tilde{l}_{j,1}^R\right], \tag{7}$$

where $\tilde{c}_{j,1} = (c_{j,1}, c_{j+1,2}, \dots, c_{J,J-j+1})$ and $\tilde{l}_t = (l_{1,t}, l_{2,t+1}, \dots, l_{J,t+J-1})$.

In order to find the overall effect of the reform, we introduce the lump sum redistribution authority (LSRA). An agent born in period $t > 1$ pays (if she loses because of the reform she pays a negative tax) in each period a lump-sum tax equal to $\tau_{t,j} = \mu_{t-j+1}c_{j,t}$, and for agents alive at the reform date, $\tau_{t,j} = \mu_{1,t-j+1}c_{j,t}$, for $j \geq t$. Next we sum those taxes from all cohorts and all periods (positive for agents who gain and negative for those who lose) and discount the sum to period 1 with the government interest rate. If the tax collection by the government is positive, it means that the overall welfare effect of the reform is positive. Next, in order to express this overall welfare gain as a percentage of the consumption of each agent, we redistribute this tax revenue to all agents in equal proportion to their consumption.

2.8. Market Clearing

The goods market clearing condition is defined as $\sum_{j=1}^{J} \pi_{j,t} N_{t-j} c_{j,t} + G_t + K_{t+1} = Y_t + (1-d)K_t$, where we denote the size of the generation born in period t as N_t. This equation is equivalent to stating that at each point in time, the price for capital and labor would be set so that the demand for the goods from the consumers, the government, and the producers would be met. This necessitates clearing in the labor and capital markets. Thus labor is supplied and capital accumulates according to $L_t = \sum_{j=1}^{\bar{J}-1} \pi_{j,t} N_{t-j} \omega_{j,t} l_{j,t}$ and $K_{t+1} = (1-d)K_t + \sum_{j=1}^{J} \pi_{j,t} N_{t-j} \hat{s}_{j,t}$, where

$\hat{s}_{j,t}$ denotes private savings $s_{j,t}$ as well as accrued obligatory contributions in the fully funded pillar of the pension system.

DEFINITION 2.1 (Equilibrium). *An equilibrium is an allocation* $\{(c_{1,t}, \ldots, c_{J,t}),\ (s_{1,t}, \ldots, s_{J,t}),\ (l_{1,t}, \ldots, l_{J,t}),\ K_t, Y_t, L_t\}_{t=0}^{\infty}$ *and prices* $\{w_t, r_t, r_t^k, r_t^G\}_{t=0}^{\infty}$ *such that*

- *for all* $t \geq 0$*, for all* $j \in [1, J]$, $(c_{j,t}, \ldots, c_{J,t+J-j})$, $(s_{j,t}, \ldots, s_{J,t+J-j})$, $(l_{1,t}, \ldots, l_{J,t+J-j})$ *solves the problem of an agent j in period t, given prices;*
- *prices are given by*

$$r_t^k = \alpha K_t^{\alpha-1}(z_t L_t)^{1-\alpha} - d;\quad w_t = (1-\alpha)K_t^{\alpha} z_t^{1-\alpha} L_t^{-\alpha}; \tag{8}$$

$$r_t = \mu_t r_t^k + (1-\mu_t) r_t^G;\quad r_t^G = \xi r_t^k; \tag{9}$$

- *the government sector is balanced, i.e.,* (2), (4)*, and* (5) *are satisfied;*
- *markets clear.*

2.9. Model Solving

We solve the model by finding the transition path between the initial and the final steady states. First, we establish the initial and final steady states. We set the length of the path to ensure that the new steady state is reached, i.e., the last generation analyzed lives its whole life in the new demographic steady state. We use the Gauss–Seidel algorithm. First we guess the path (or the single value of capital per worker in the steady states). Then we compute w and r. Subsequently y is computed and used to calculate variables related to the pension system and government sector, such as G, T, S, D, Υ, as well as the individual benefits $b_{1,j}$ and $b_{2,j}$. Following the assumption about consumers' perfect foresight, choice variables c_j, s_j, and l_j are computed. Finally, k is updated to satisfy market clearing. This procedure is repeated until the difference between k from subsequent iterations is negligible.[17] Once equilibrium is reached, utilities are computed and discounted to reflect the utility of the first generation in our model, i.e., 20-year-olds.

The model is solved twice. First, the benchmark scenario is computed for no policy change, but with changes in demographics and in productivity (see Section 3). Second, the model is solved for the analyzed policy change scenario. In both these runs, utility for all generations is computed. Finally, we convert the net welfare for each cohort into a consumption equivalent; while doing that we use utility at $j = 1$. Because in our model some cohorts in the first period are older, we use their utility at their age at the reforms date for consumption-equivalent computations. Furthermore, in our model, consumption equivalent is expressed as a permanent percentage change in lifetime consumption. The net balance of this welfare measure informs us about the overall efficiency of the reform, as discussed in the preceding.

2.10. Fiscal Closure Scenarios

The benchmark scenario—no policy change—involves maintaining the notional DB pay-as-you-go pension system, subject to demographic change and exogenous productivity growth slowdown. This simulation yields reference paths for capital, income, labor supply, and consumption, as well as the vector of utilities across cohorts.

We consider two main scenarios: tax closures and debt closure. For comparison with Okamoto (2005a) and Nishiyama and Smetters (2007), we also allow a scenario where the lump-sum tax (Υ) adjusts. In the tax closures, lump-sum, labor, or consumption taxes adjust fully, whereas debt is held constant. In the debt closures, financing of the gap in the pension system is levied on future generations; i.e., deficits are financed with government debt. We allow the debt to grow for the first 60 years after the reform or until an upper bound of 60% ratio to GDP[18] is hit (whichever happens sooner). After 60 years the debt is gradually repaid to bring the debt share in GDP to the value from the first steady state (i.e., 45%). We keep the debt at the threshold and repay it using labor tax or consumption tax.[19] Given that retirees pay labor income tax (stylized to Polish legislation), the difference between labor and consumption types of closure in our model is not so much *who* pays, but rather *how much* is paid by each cohort.

3. CALIBRATION AND BASELINE

Calibration was pursued in two stages. First, using microeconomic evidence and the general characteristics of the Polish economy, we established reference values for preferences, life-cycle productivity patterns, taxes, technology growth rates, etc. (see Table 1). Given this parameterization, we calibrated the discount factor δ so that the combined interest rate in the economy in the initial steady state was close to 7.4% and d so that the aggregate investment rate matched the one observed in the data, i.e., approximately 21%.[20]. In practice, the effective annual interest rates recorded on the savings in the funded pillar II of the pension system amount to an annual average of 7.4% in real terms. Nishiyama and Smetters (2007) calibrate the interest rate to 6.25% for the U.S. economy. It is thus reasonable to assume a slightly higher value for a catching-up country scarce in capital.

3.1. Demographics

We use the demographic projection for Poland by EUROSTAT. In the model, we use as input the data for the number of 20-year-olds born at each period in time and mortality rates as implied by the projection. Thus, the number of agents in each age cohort j at each point in time t is actually a number of 20-year-olds who survived till this age. Demographics is assumed to be constant after 130 periods (50 periods of the projection + 80 periods for 20-year-olds in the last year of the projection). In addition to the scenario matched to the projection, we also consider

TABLE 1. Calibrated parameters

Demographic scenario and the rate of technological progress		Matched to data/projections $\beta = 1$ $\omega = 1$	$\beta = 1$ ω—D97	$\beta = 0.9$ $\omega = 1$	$\beta = 0.9$ ω—D97	Alternative $\beta = 1$ ω—D97
α	Capital share	0.31	0.31	0.31	0.31	0.31
τ_l	Labor tax	0.11	0.11	0.11	0.11	0.11
ϕ	Preference for leisure	0.527	0.560	0.532	0.565	0.552
δ	Discount rate	0.984	1.008	0.989	1.01	1.006
d	Depreciation rate	0.06	0.04	0.06	0.06	0.06
τ	Total soc. security contr.	0.061	0.061	0.061	0.061	0.061
ρ	Replacement rate	0.251	0.152	0.252	0.153	0.129
		Resulting				
$\Delta k_t/y_t$	Investment rate	21.5	21.3	21.4	21.4	21.2
r	Interest rate	7.1	6.9	7.2	7.1	5.0

Note: D97 denotes calibration according to the Deaton (1997) decomposition. Alternative demographics and the rate of technological progress stand for growing population and lower initial technological progress rate, as displayed in Figure 1.

a case with nondecreasing fertility, keeping the mortality rates as projected. This more favorable demographics is characterized by lower old-age dependency ratio and positive contributions of population to output; see Figure 1.

3.2. Productivity Growth (γ_t)

The model specifies labor-augmenting growth of technological progress, $\gamma_{t+1} = z_{t+1}/z_t$. The values for the 50-years-ahead projection were taken from the forecast by the Aging Work Group of the European Commission, which comprises such time series for all EU member states; see Figure 1. The overall assumption behind these forecasts is that countries with lower per capita income will continue to catch up, but around 2030, all countries' exogenous productivity growth will be converging slowly toward the steady state value of 1.7% per annum. In addition to the scenario matched to the projection, we consider also an alternative path with starting values similar to the ones observed for advanced economies, i.e., approximately 2% per annum.

3.3. Age-Specific Productivity (ω_j)

We allow for two paths: a flat age–productivity profile and one derived from Deaton (1997).[21] The de jure retirement age is 60 for women and 65 for men, but the effective exit age is lower.[22] The de jure retirement age is assumed to reach 67 for men in 2018 and for women in 2040. These legislative and cohort effects

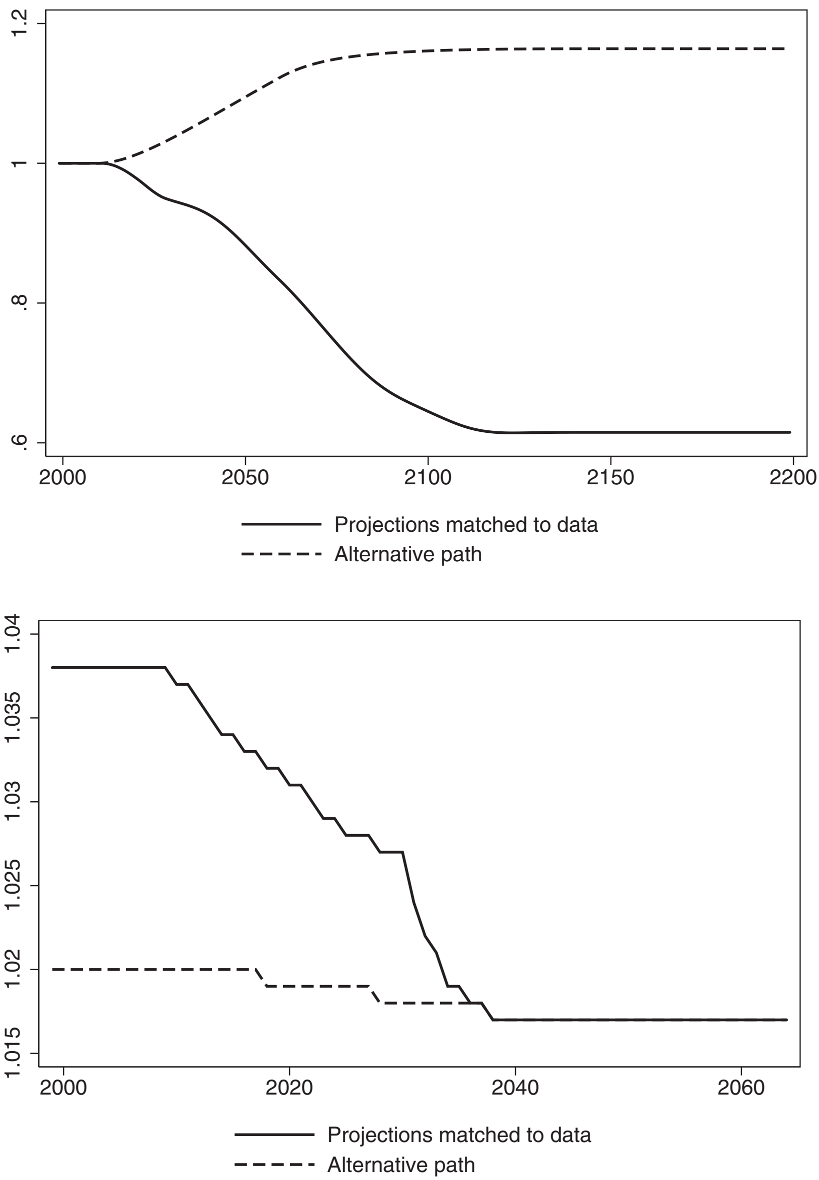


FIGURE 1. (Top) Population (relative to 1999) according to the demographic projection and an alternative scenario. *Source*: EUROSTAT demographic forecast until 2060. (Bottom) Labor-augmenting productivity growth rate according to the projection and an alternative scenario. *Source:* European Commission.

are reflected in a path of retirement age in our model, which is the same along the path in the baseline and in the reform scenario.

3.4. Preference for Leisure (ϕ)

Agents' preference for leisure/consumption is directly responsible for labor supply decisions, so we pick it to replicate a labor market participation rate of 56.8% (pre-reform value). The final value amounts to 0.53, which seems reasonable: average hours worked in the Polish economy amount to approximately 2050,[23] i.e., 51.3% of the total workable time.

3.5. Impatience (Discount Factor, δ)

The value δ was chosen to match the interest rate of 7.4% on the asset portfolio, as described in the preceding. We also set the return on government bonds at $\xi = 1/3$ of the return on capital assets to match the corresponding ratio observed in the data on developed countries. In Poland over the period 1995–2005, the return on government bonds was equal to 45% of the commercial market interest rate, although the proportion is decreasing. There is an additional discounting parameter β, whose values are set in line with the literature. Namely, we simulate the model for two values of $\beta = \{1, 0.9\}$, where $\beta = 1$ implies no time inconsistency. The depreciation rate d is calibrated to match the investment rate in the economy, given δ.

3.6. Replacement Rate (ρ)

We set the replacement rate to match the 5% ratio of pensions to GDP in 1999. Depending on the selected ω scenario, the actual value for the replacement rate differs. The effective rate of contribution was set so that the pension system deficit as a percentage of GDP in the original DB steady state matches the one observed in the data, i.e., 0.8%. Although the de jure contribution rate amounts to 19.52% of payroll, the actual effective contribution rate consistent with our model amounts to approximately 6.1%.

3.7. Taxes

Labor income tax (τ_l), which amounts de jure to 18% and 32%, was set at an effective 11%, which matches the rate of labor income tax revenues in the aggregate employment fund. For the social security contributions, it is much harder to find a matching relationship. The consumption tax τ_c was set at 11%, which matches the rate of revenues from this tax in aggregate consumption in 1999. There are no tax redemptions on capital income tax, so $\tau_k = 19\%$. Obligatory savings in the fully funded pillar are exempt from capital income tax, to follow the actual legal design.

3.8. Savings and Wealth

The pension reform implied that the SIF needed to compute the so-called initial capital for all cohorts participating in DC system. Intuitively, the initial capital reflects the counterfactual scenario on what would be the stock of assets in the NDC individual account had the NDC system been established in the past. We use the 1% sample of the adult population made available by the SIF to infer the age-specific distributions of wealth. To ensure comparability with the model, initial capital is expressed in terms of average wage (w).

3.9. Baseline Scenario

Naturally, demographic and productivity changes are reflected in the baseline scenario. Because this is the reference for comparison to the policy scenarios, we allow parallel changes in the baseline. For example, in the scenario with labor tax closure, the labor tax grows to satisfy the budget constraint both in the baseline DB PAYG system and in the transition to the new, partially funded DC system. This is important for our findings. If contributions to the pension system are not changed in the DB baseline scenario on account of increasing longevity and decreasing overall labor supply, the accumulated debt in the pension system grows substantially, as shown in Figure 2.

The nonmonotonic behavior of benefits in Figure 2 (i.e., wiggles) follows from the changes in the retirement age. Because age is discrete, if the retirement age increases in a particular year, then there are no cohorts retiring, and two cohorts will retire in a subsequent year. The opposite effect is seen if the retirement age is decreased. This nonmonotonicity is translated to nearly all simulations in our model.

4. RESULTS

In the following we discuss the welfare effects of fiscal closures and then move on to the macroeconomic effects of pension system reform under various fiscal closures.

4.1. Welfare Effects

The initial steady state is the same across all specifications with the calibration details described in Section 3. On the baseline transition path we consider the following fiscal closures: lump-sum tax, labor tax, consumption tax, debt with adjustment in labor tax, and debt with adjustment in consumption tax. Taxation adjustment is only triggered if the debt passes the threshold ratio to GDP, set at 60%. The same five scenarios are possible in the reform scenario, which implies a total of 25 combinations of the baseline and reform paths as far as fiscal closures are concerned.

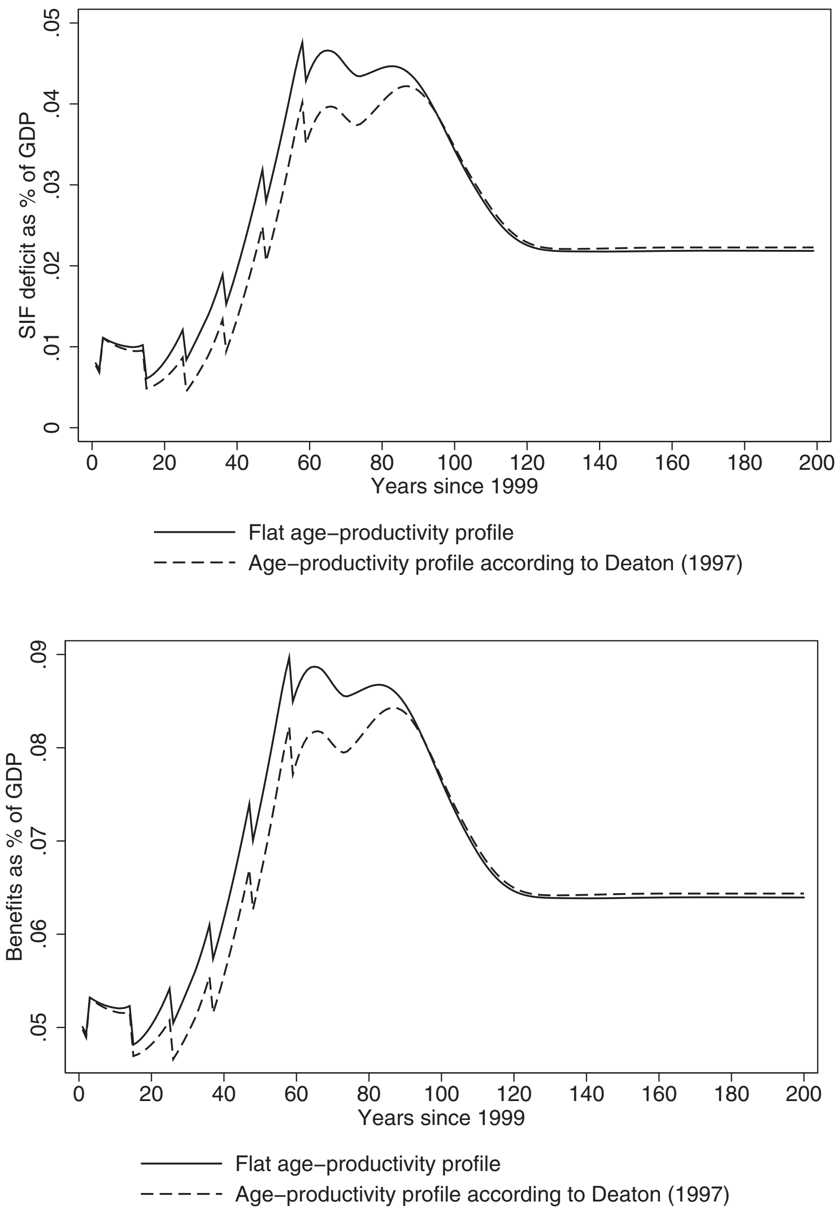


FIGURE 2. Cumulated changes in SIF balance and pension share in GDP in the baseline scenario of no policy change (with no time inconsistency).

Overall efficiency and fiscal closures. The gap implied by the privatization of the social security system may be financed by taxing the currently working generations and/or taxing future generations via raising public debt. Although proportional taxation is distortionary, it may indeed be the case that a relatively small distortion across all possible cohorts (because of initial increase in the public debt) is superior in terms of welfare to a larger distortion condensed in a smaller fraction of cohorts. Thus, comparing the welfare effects of various fiscal closures is an empirical question.[24] The contribution of this paper is a comparison of welfare effects depending on the fiscal closure scenarios.

Comparing within rows various closures in reform for the same baseline fiscal adjustment, we can observe the role played by fiscal closures themselves in Table 2. In fact, the differences between the fiscal closures in the reform scenario are relatively large, amounting to roughly 20–30% of the overall welfare effect. Comparing between the rows serves as a robustness check of our simulations, showing that these large differences do not stem from particularities of one selected baseline. Neither is the conclusion driven by the calibration or the assumptions concerning the trajectories for demographics and technological progress. Indeed, more favorable demographics and slower technological progress yield somewhat smaller gains, but still the discrepancy within rows is substantial, ranging between 15 and 30% of the maximum overall welfare gain. Across the board, the proposed reform is welfare-enhancing; i.e., after compensating all the generations that lose out as a result of the reform, LSRA has positive net wealth to redistribute irrespective of the fiscal closure.

Regardless of the specification, it is the debt combined with a labor tax that yields the highest efficiency gain. Thus, although the labor tax rate needs to grow when the debt exceeds the constitutional threshold, in per capita terms this increase is lower than the increase in the scenario of no policy change. This suggests that a politically viable solution is actually welfare-enhancing when compared with fiscal closures in which the majority of the costs of the reform are borne by transition cohorts.

These results have important policy implications. Although efficiency gain in this particular design of the reform seem to be universal, there is a wide discrepancy between the size of the overall welfare gain depending on the fiscal closure. In fact, if we compare the "best" (debt with labor tax) with the "worst" (consumption tax), the differences are as large as 1.28% of permanent consumption, i.e., more than half of the overall pension reform effect in the case of the worst' fiscal closure and nearly a third in the case of the best fiscal closure.

Decomposing the sources of welfare effects. The second contribution of our paper is decomposing which part of the welfare effects is attributable to forming a prefunded pillar and which follows from changing a defined benefit mechanism to a defined contribution one. The latter involves lowering the replacement rates, whereas the former generates a fiscal gap to be financed with (contemporaneous) taxes or public debt.

TABLE 2. Welfare effects: A comparison of the fiscal closures for the pension system reform

Fiscal closure in baseline	Fiscal closure in reform Υ	τ_c	debt + τ_c	τ_l	debt + τ_l	max − min (in % of a max)
Demographics and productivity paths matched to the projections						
Υ	3.19	2.79	3.44	3.39	4.07	31.4%
τ_c	3.03	2.68	3.4	3.28	3.96	32.3%
debt + τ_c	3.06	2.7	2.79	3.3	3.36	19.6%
τ_l	2.96	2.66	3.26	3.19	3.89	31.6%
debt + τ_l	2.99	2.66	2.74	3.21	3.26	18.4%
Alternative demographics and productivity paths						
Υ	2.53	2.36	2.84	2.76	3.25	27.3%
τ_c	2.44	2.30	2.80	2.69	3.17	27.4%
debt + τ_c	2.46	2.32	2.40	2.71	2.78	16.6%
τ_l	2.41	2.27	2.74	2.64	3.14	27.7%
debt + τ_l	2.43	2.29	2.37	2.67	2.74	16.3%

Note: Numbers signify a consumption equivalent (as a percentage of permanent consumption) under the parameterization of $\beta = 1$ and productivity following Deaton (1997). As described earlier, welfare for each cohort is discounted to its age of 20 and stationarized (to adjust for economic growth). It is expressed as utility (consumption equivalent) net of transfers necessary to compensate for the losses induced by the lack of reform. Table for alternative parameterizations available upon request.

Analysis of the effects across cohorts and between the components of the reform reveals that redistribution is indeed needed to alleviate the costs for the majority of the living cohorts. Figure 3 demonstrates the decomposition results with a reform scenario corresponding to the fiscal closures on the diagonal of Table 2. Clearly, lump-sum taxation involves high welfare loss for relatively poor old cohorts, which reveals a particular characteristic of this type of fiscal closure in the OLG context of heterogeneous agents (w.r.t. age). Proportional taxation on labor or consumption shows that all the welfare costs of financing the gap are in fact borne by the cohorts alive at $t = 0$, whereas the future cohorts experience nothing but welfare gains due to PAYG as a result of fully funded reform. In comparison, fiscal closure via public debt makes it possible to spread the costs of financing the pension system gap (more) equally across generations. In fact, the overall effects of forming the prefunded pillar are positive, but this value is small, compared with the effects from a DB $\Rightarrow$ DC change.

Although it seems that welfare is somewhat smaller in the case of financing the reform with debt (approximately 0.1–0.15 percentage points of permanent consumption), this type of fiscal closure works similarly to the LSRA mechanism. In fact, debt automatically redistributes between cohorts, whereas the political feasibility of LSRA remains doubtful. On the other hand, debt closures involve some modest efficiency disadvantage in terms of welfare, which implies that substantially raising debt could essentially eliminate the welfare cost of forming

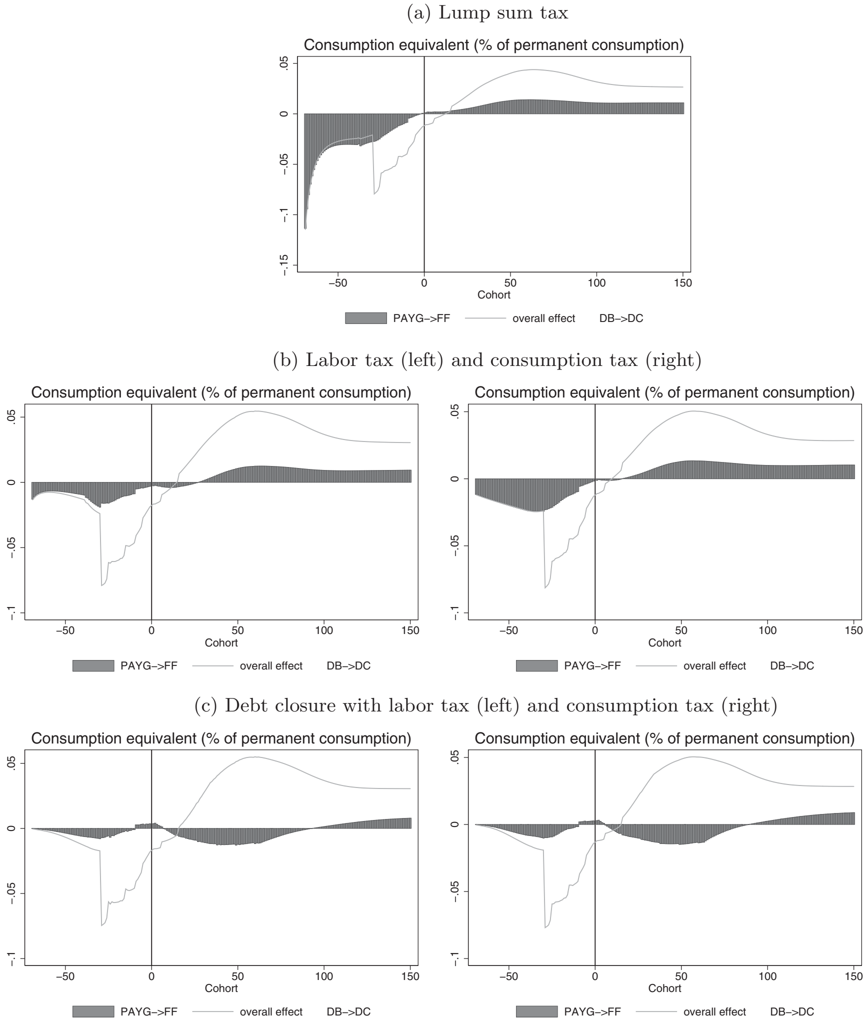


FIGURE 3. Decomposition of welfare effects.

the prefunded pillar, but at the expense of overall welfare gains from the reform.[25] The extent of fiscal adjustment in each of the closures is considerable and justifies relatively large welfare effects; see Figure 4. Consumption, labor, and lump-sum taxes grow in the initial phase of the pension system change by roughly 2–3 percentage points, whereas this increase is approximately 1–1.5 percentage points smaller in the baseline. However, this result is due to the fact that actual deterioration in the dependency ratio occurs only about 30 years after the reform. Tax rates are subsequently considerably lower in the reform scenario than in the original DB equilibrium, which follows form the fact that the SIF deficit does

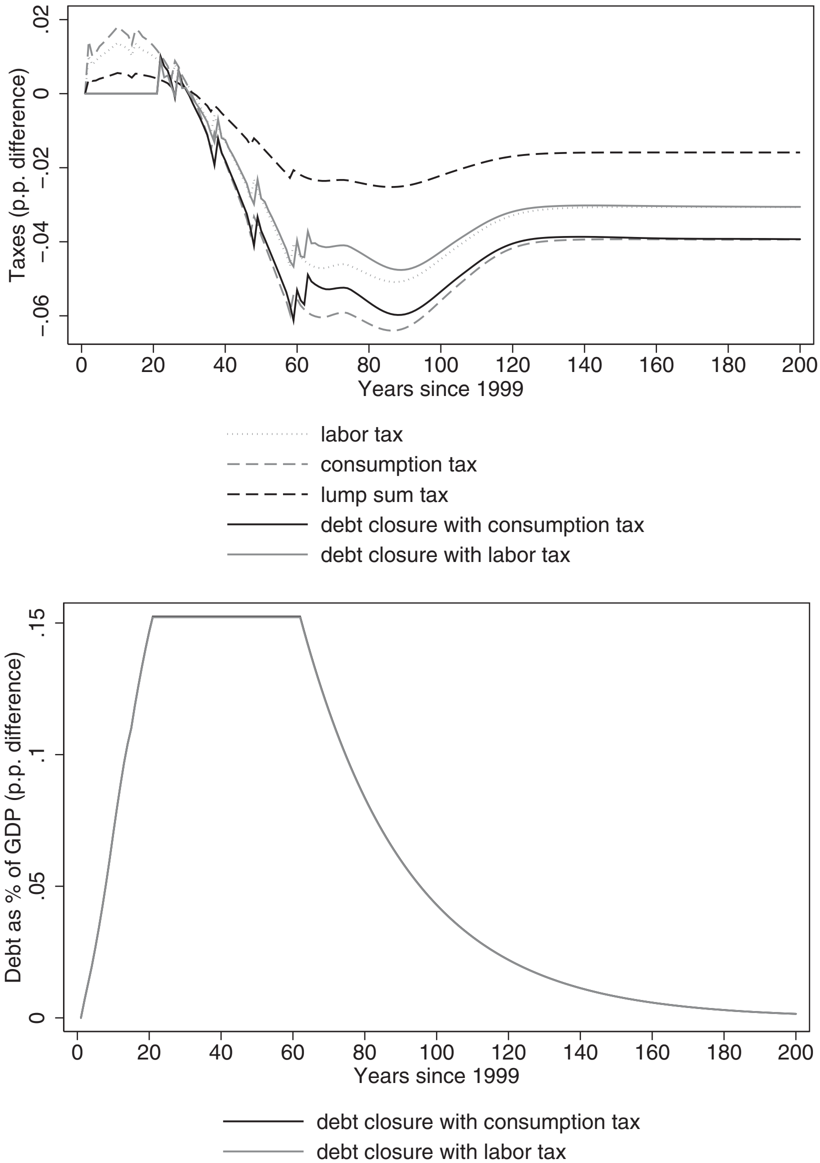


FIGURE 4. Changes in taxes and debt share (lump-sum tax in baseline scenario).

not need to be financed with general taxes. Eventually, the amount of excessive taxation reaches as much as 50% of the tax rates.

Susceptibility of results to the calibration. The results we obtain could be susceptible to the specification of time inconsistency or age-productivity patterns.

TABLE 3. Welfare effects for all analyzed fiscal closures depending on parameterization

Fiscal closure in reform scenario	$\beta = 1$		$\beta = 0.9$	
	$\omega = 1$	ω—D97	$\omega = 1$	ω—D97
debt + τ_c	3.74	3.44	0.99	2.54
debt + τ_l	4.10	4.07	2.42	2.95
τ_c	3.29	2.79	1.43	2.05
τ_l	3.63	3.39	1.83	2.43
Υ	3.10	3.19	1.22	2.21

Note: Numbers signify a consumption equivalent (in % terms). In the baseline scenario, fiscal closure is given by lump-sum taxation (Υ). Results for other baseline fiscal closures available upon request.

Table 3 displays the robustness check. The more myopic the agents are, the lower is the welfare gain from the reform across all scenarios. Indeed, although the reform is generally efficient, the gains decrease with the extent of time inconsistency, as suggested by Imrohoroglu et al. (2003). This result implies that a disciplining device in the form of forced pension savings with a (partially funded) DC scheme are in fact welfare-deteriorating for the generations living during the transition period between the original and the new pension system. Although the living generations benefit from the debt closure, future generations will experience welfare gain from lower implied taxation. However, agents with time-inconsistent preferences would rather have lower (welfare) costs today than gains in the future.

4.2. Changes in the Economy

The gain in GDP over the baseline scenario amounts to approximately 1% in a decade and may exceed 2% over 50 years; see Table 4.[26] This output gain follows almost entirely from faster capital accumulation, as changes in the labor supply are minuscule. In fact, capital grows under any of the reform scenarios by approximately 7% to 9% more than under the status quo of no policy change, depending on age–productivity patterns.[27] Most of the changes are driven by the emergence of the funded pillar: in the initial phase of the reform the financing of the reform via debt crowds out the private savings, thus lowering the speed of capital accumulation relative to tax scenarios. Once the debt stops crowding private savings out, the rate of capital accumulation speeds up in the reform scenarios relative to the status quo of no policy change.

The effects are modest when compared with the literature. For example, Nishiyama and Smetters (2007) find as much as a 10% differential in output. However, it is important to recognize that we analyze a reform that involves no change in the contribution rate, and only one-third of the contributions is directed to the funded pillar, with initially only partial participation. A stronger effect would

TABLE 4. Macroeconomic effects of the reform, Υ fiscal closure in baseline scenario, and demographics and technological progress paths matched to data/projections

		GDP				Labor supply				Capital			
Fiscal closure in the reform scenario		$\beta = 1$		$\beta = 0.9$		$\beta = 1$		$\beta = 0.9$		$\beta = 1$		$\beta = 0.9$	
	Period	D97	flat	D97	flat	D97	flat	D97	flat	D97	flat	D97	flat
Labor tax	10	1.00	1.01	1.00	1.01	0.99	0.99	0.99	0.99	1.01	1.02	1.01	1.02
	30	1.01	1.02	1.01	1.02	0.99	1.00	0.99	1.00	1.05	1.05	1.05	1.05
	50	1.02	1.02	1.02	1.02	0.99	1.01	0.99	1.01	1.07	1.08	1.07	1.08
	∞	1.02	1.02	1.02	1.02	0.99	1.01	0.99	1.01	1.06	1.06	1.06	1.07
Debt with labor tax	10	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	0.99	1.00
	30	1.01	1.01	1.01	1.01	0.99	1.00	0.99	1.00	1.02	1.02	1.02	1.02
	50	1.01	1.01	1.01	1.01	1.00	1.01	1.00	1.01	1.05	1.05	1.05	1.05
	∞	1.02	1.02	1.02	1.02	0.99	1.01	0.99	1.01	1.06	1.06	1.06	1.07
Consumption tax	10	1.00	1.01	1.00	1.01	0.99	1.00	0.99	1.00	1.01	1.02	1.01	1.02
	30	1.02	1.02	1.02	1.02	0.99	1.00	0.99	1.00	1.05	1.06	1.05	1.06
	50	1.02	1.02	1.02	1.02	0.99	1.01	0.99	1.01	1.08	1.08	1.07	1.08
	∞	1.02	1.02	1.02	1.02	0.99	1.01	0.99	1.01	1.07	1.07	1.07	1.07
Debt with consumption tax	10	1.00	1.00	1.00	1.00	0.99	1.00	0.99	1.00	0.99	0.99	0.99	0.99
	30	1.00	1.01	1.00	1.01	0.99	1.00	0.99	1.00	1.02	1.02	1.01	1.02
	50	1.01	1.02	1.01	1.02	0.99	1.01	0.99	1.01	1.05	1.05	1.05	1.05
	∞	1.02	1.02	1.02	1.02	0.99	1.01	0.99	1.01	1.07	1.07	1.07	1.07
Lump-sum tax	10	1.00	1.01	1.00	1.01	1.00	1.00	1.00	1.00	1.01	1.02	1.01	1.02
	30	1.02	1.02	1.02	1.02	0.99	1.01	0.99	1.01	1.05	1.06	1.05	1.06
	50	1.02	1.03	1.02	1.03	1.00	1.02	1.00	1.02	1.08	1.09	1.08	1.09
	∞	1.02	1.02	1.02	1.02	0.99	1.01	0.99	1.01	1.06	1.07	1.06	1.07

Note: Numbers signify ratio to baseline scenario of no policy change. Long run denotes the new steady state after 250 periods. D97 denotes calibration according to the Deaton (1997) decomposition.

have to originate either from private, voluntary savings or from the labor market. Savings increase by as much as 6% in one generation, which is considerable by all standards. Because the labor market is frictionless and perfectly elastic in our model, one should observe little aggregate change. Naturally, there are also some incentive effects for the labor supply, but as long as households cannot influence their retirement age, the effects of system change are bound to be relatively small.

Susceptibility of results to the calibration. Neither the extent of time inconsistency nor the age-productivity pattern is neutral to the change in the pension system (Figures 5a–5b). With the Deaton (1997) pattern, labor supply grows with age, reflecting higher returns to labor. With aging populations, pensions grow under

Table 5. Macroeconomic effects of the reform, Υ fiscal closure in baseline scenario, alternative demographics and technological progress paths

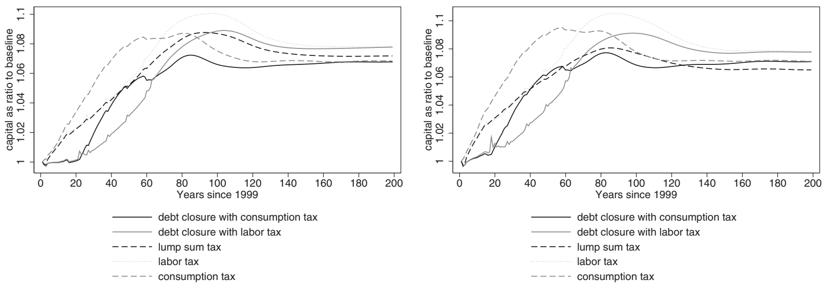
Fiscal closure in the reform scenario	Period	GDP $\beta = 1$ D97	Labor supply $\beta = 1$ D97	Capital $\beta = 1$ D97
Labor tax	10	1.00	0.99	1.01
	30	1.01	0.98	1.03
	50	1.01	0.99	1.04
	∞	1.02	0.99	1.07
Debt with labor tax	10	1.00	1.00	1.00
	30	1.00	0.98	1.01
	50	1.01	0.99	1.02
	∞	1.02	0.99	1.07
Consumption tax	10	1.00	0.99	1.01
	30	1.01	0.99	1.05
	50	1.02	0.99	1.06
	∞	1.02	0.99	1.06
Debt with consumption tax	10	1.00	0.99	1.00
	30	1.01	0.99	1.02
	50	1.01	0.99	1.03
	∞	1.02	0.99	1.06
Lump-sum tax	10	1.00	1.00	1.01
	30	1.01	0.99	1.03
	50	1.01	0.98	1.05
	∞	1.02	0.98	1.06

Note: Numbers signify ratio to baseline scenario of no policy change. Long run denotes the new steady state after 250 periods. D97 denotes calibration according to Deaton (1997) decomposition.

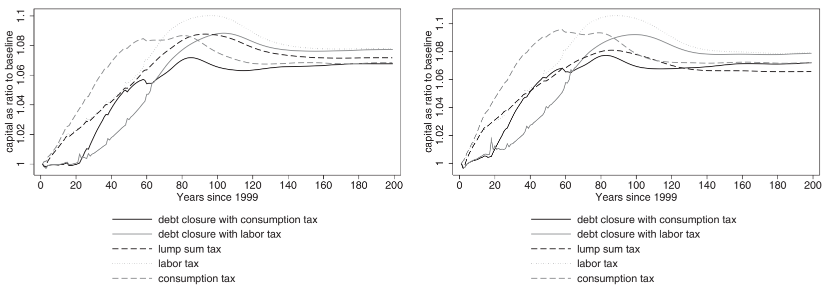
DB, reducing the need for private savings, whereas under DC, private savings grow more to smoothen lifetime consumption. These effects, however, are minor and matter more for the timing of the increase/decrease in the rate of capital accumulation than for its actual level.

The results suggest that for (a large degree of) time inconsistency, the contribution rates to the capital pillar become more binding. Note that the interest rate earned on private savings is subject to capital taxation, whereas compulsory savings in the funded pillar are not, thus offering a relatively high rate of return. Hence, it is not the choice of *how* to save but rather *if* to save at all that is binding for the myopic agents. This finding is consistent with Blake (2000) and others, who emphasize the sustainability of the funded schemes rather than higher rates of return.

(a) Deaton (1997) productivity (left) and flat age productivity profile (right), *no* time inconsistency.



(b) Deaton (1997) productivity (left) and flat age productivity profile (right), *with* time inconsistency.



(c) Deaton (1997) productivity, *no* time inconsistency, and alternative demographic and productivity projection.

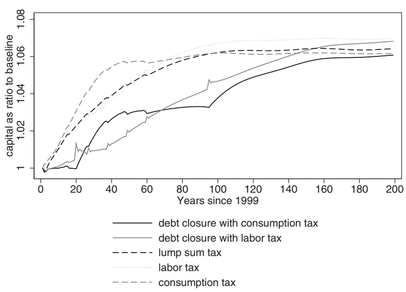


FIGURE 5. Changes to capital in reference to no-policy-change scenario (ratio).

5. CONCLUSIONS

This paper has addressed the welfare effects of various fiscal closures in switching from a defined benefit pay-as-you-go system to a partially funded defined contribution system. Although the efficiency of such types of reform has already been addressed in the literature, there is 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. In addition, we provide a decomposition of the welfare changes due to the pension (DB to DC) and the changes due to the financing mechanism (PAYG to partial prefunding). Although the reform itself has welfare effects, so does the fiscal adjustment necessary to implement the reform.

Our findings reveal that the fiscal closure itself can contribute/deduct up to approximately 15–30% of the overall welfare effect of the pension system "privatization." Financing the reform with public debt makes it possible to spread the costs of establishing the prefunded pillar fairly across all generations, introducing automatic redistribution between cohorts. We also demonstrate that in the simulations matched to the demographic productivity projections, this fiscal closure yields superior welfare gains when compared with taxation of the generations living at the moment of the reform. The results are robust to a number of parametric choices (time inconsistency and life-cycle productivity patterns) as well as to the assumptions concerning the demographic projection and the technological progress rate.

The policy implications of this study are quite optimistic. First, the politically viable fiscal closure—rarely employed in the earlier literature—actually yields the highest welfare gains. This suggests that a number of reforms that were not as efficiency-enhancing in previous work could be more beneficial if coupled with a debt closure in reality. An important feature of our model is the debt threshold, which necessitates some tax adjustment, thus making debt fiscal closure actually fairly prudent. Second, we show that debt closure is an automatic and credible "redistribution authority," which helps to enforce transfers between the cohorts, unlike tax closures, which would require the government to act as a LSRA. Third, we show that although the majority of the fiscal gap comes from establishing the prefunded pillar, the majority of the welfare effects come from the downward adjustment in pensions—not from the fiscal cost of establishing the pillar. This finding is universal across the fiscal closures and suggests that the weight of the policy debate should be shifted to the fiscal policy accompanying the reform rather than the reform design.

NOTES

1. Some countries (e.g., France, Italy, Germany) partially reduce the generosity of the social security system and attempt to raise the contributions base by increasing participation and compliance. Macroeconomic simulations show, however, that such measures are far from satisfactory and at best delay the fiscal consequences, e.g. EC (2012).

2. Recently McGrattan and Prescott (2013) advocated in favor of abolishing a PAYG DB pension system in the United States *without* replacing it with a mandatory (partially) funded one. They show universal welfare gains from no pension system at all.

3. In addition, reforms of the pension system typically alter the proportions between implicit and explicit public debt; see Genakoplos et al. (2000); Kuhle (2010).

4. One of the reasons, as may be understood from Fehr (2009), is that these models still focus on relatively fundamental questions (the 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. There have been a number of attempts to extend these models to comprise a political economy component and test the political stability of the reform with changing demographics; cf. Galasso (1999); Kumru and Piggott (2010) and Wright et al. (2012).

5. Huggett and Ventura (1999) discusses the distributional effects of social security system reform, but compares only the steady states, without explicitly analyzing the transition between the old and the new system.

6. See Lindbeck and Persson (2003), as well as Fehr (2009), for an overview of the abundant literature.

7. In the case of Europe, as demonstrated by Boersch-Supan and Ludwig (2010), the fiscal effects are particularly large because of to more rapid aging. In addition, demography has one more consequence for the outcomes from a modeling perspective. Mortality rates discount future consumption, income, and utility. Consequently, lower mortality implies more patience in discounting the future. Uncertainty about the pace of mortality reduction may play an important role as well; e.g., Sanchez-Marcos and Sanchez-Martin (2006).

8. Conceptually, LSRA is much more than the way to compute welfare—it is a redistribution mechanism, which alleviates potential inequality in the distribution of welfare changes due to the reform. Technically, LSRA finances the transfers to compensate welfare losses through lump-sum taxes on generations that experience welfare gains. The intermediate budget of LSRA—i.e., once all losses are compensated for and prior to distributing the reminder—shows the overall efficiency gains due to the reforms.

9. In terms of geography, originally the majority of analyses focused on the U.S. economy and subsequently also the U.K. economy, e.g., Kotlikoff et al. (1999) and Cipriani and Makris (2001). Subsequently, however, there has been a number of attempts to simulate various reforms and features of the system in Germany [e.g., Coppola and Wilke (2010); Bucher-Koenen and Lusardi (2011)], Spain [e.g., Díaz-Giménez and Díaz-Saavedra (2009)], a few selected EU countries [Ludwig and Vogel (2009)], and Europe as a whole [e.g., Feldstein and Siebert (2002); Aglietta et al. (2007); Keuschnigg et al. (2012)]. An abundance of papers on aging and pension reform in Japan includes also Okamoto (2005a,b), who compares the welfare effects of various pension reforms with financing coming from labor taxation or consumption taxation. To the best of our knowledge, for the Central and Eastern European countries, with the exception of Slovenia, cf. Verbič et al. (2006) and Verbič (2007), there are no full-fledged OLG models. Li and Mérette (2005) offers an analysis for China.

10. The system is completed by a third pillar, where savings are also exempt from the capital income tax, but the contributions are voluntary and subject to a cap. The third pillar is not popular, with only about 1.3% of the working population contributing to voluntary pension savings schemes. Thus, we ignore this feature in subsequent analysis, and private savings are in general subject to capital income tax.

11. Note that this is a conservative assumption in the sense that PAYG DB systems are more fiscally viable if the population stabilizes.

12. We assume that the retirement age is time-varying and exogenous (calibrated to the Polish data; see Section 3).

13. We follow Imrohoroglu et al. (2003), who discuss various alternatives to this formulation of time-inconsistency, as well as its microfoundations. Caliendo (2011) generalizes Imrohoroglu et al. (2003) for a continuous-time case. Sometimes time inconsistency involves the duration of economic activity rather than savings; cf. Findley and Caliendo (2015).

14. As noted by Nishiyama and Smetters (2007), although privatizing social security can improve labor supply incentives, it can also reduce risk sharing. With randomized and noninsurable shocks to individual productivity, the original conclusions of Feldstein's highly stylized model do not necessarily hold. Similar conclusions originate from models incorporating time inconsistency into consumer choice, [Imrohoroglu et al. (2003); Bassi (2008); Fehr et al. (2008); Fehr and Kindermann (2010); van de Ven and Weale (2010); Kumru and Thanopoulos (2011)]. An alternative approach has been proposed by Gul and Pesendorfer (2004) with recursive and separable dynamic self-control preferences. Specifically, the pension system is viewed as a disciplining device or technology (in terms of savings), whereas the PAYG component of the pension systems usually replaces the otherwise absent insurance mechanism (at the tax/expense of inefficiency). In a world where savings for future expenditure are too low, incentives to raise them to an optimal level may actually help improve social welfare,

despite reducing leisure and consumption in the working periods. The reasons that savings may be too low, as analyzed in the literature, include unexpected longevity and/or negative income shock in the working period, as well as myopia, time-inconsistent preferences, and insufficient financial literacy.

15. Our treatment of the labor market, for the sake of brevity, assumes no frictions. Building on earlier developments, Keuschnigg et al. (2012) develop a framework with social assistance and unemployment, as well as full-fledged search and matching. In addition, a number of attempts have been made to endogenize the retirement age decision, e.g., Vogel et al. (2012) .

16. In fact, the legislation necessitates averaging over the best out of the last twenty years of professional activity. We replicate this feature of the pension system in computations.

17. In each iteration, error is computed as the l_1-norm of the difference between capital vectors in subsequent iterations.

18. We experimented with a number of higher and lower values, and the results were qualitatively unaffected by the choice of this parameter.

19. The duration of 80 years was chosen because this is as long as the youngest transition cohort will live. The second condition for setting the bound on debt growth is dictated by the fact that even if economically stable over the long run, some levels of reform-induced debt may be politically infeasible; see Andolfatto and Gervais (2008) and Cabo and Garcia-Gonzalez (2014).

20. Depending on the period over which the average is taken, it ranges from 20.8% for five years ahead and five years postreform to 23.1% for two years before— span and 24.1% for one year before–after span. The average for the period between 1995 (first reliable post-transition data) and 2010 amounts to 20.7%.

21. There is a considerable body of literature analyzing changes in productivity across the life cycle. The major difficulty from an empirical perspective consists typically of separating cohort effects (consistent with downward sloping pattern) from actual changes in individual productivity. The majority of microeconometric analyses confirm an inverted U-shaped pattern; cf. Skirbekk (2004) as well as a forthcoming special issue of *Labor Economics* (Vol. 22, 2013). On the other hand, some analyses show that, when cohort effects and self-selection are controlled for adequately, in fact the age–productivity relation is fairly flat and—if anything—slightly increasing until the age of 65 [Boersch-Supan and Weiss (2011)].

22. SIF Annual Reports.

23. Conference Board, averaged for 1999–2012 (*ahwpol* from the Conference Board Total Economy Database).

24. Please note that the actual number of future cohorts is irrelevant for the computation of the overall efficiency measure; see Section 2.

25. Debt hits the upper bound (60% of GDP) already after 15–20 periods in the reform scenario and after 30–40 periods in the baseline scenario. Thus, in most of the periods it is actually the tax closures that operate, which explains the negligible difference between the two types of fiscal closures. If debt were allowed to go beyond 60% of GDP, more redistribution would be possible. This threshold is rooted in the constitution as well as the Treaty of Maastricht.

26. We show the macroeconomic effects prior to the redistribution by the LSRA.

27. As has been visible in our calibrations, the initial replacement rate may indeed be lower in those simulations where productivity grows in age. This explains why flat age profiles yield higher capital accumulation and thus higher output ceteris paribus.

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APPENDIX: SOLUTION OF THE CONSUMER PROBLEM

Denote a stream of consumption for an agent aged j in period t as $\tilde{c}_{j,t} = (c_{j,t}, c_{j+1,t+1}, \ldots, c_{J,t+J-j})$ and a stream of labor $\tilde{l}_{j,t} = (l_{j,t}, l_{j+1,t+1}, \ldots, l_{J,t+J-j})$. The consumer at age j in period t optimizes her lifetime utility

$$U_j(\tilde{c}_{j,t}, \tilde{l}_{j,t}) = u_j(c_{j,t}, 1 - l_{j,t}) + \beta \sum_{s=1}^{J-j} \delta^s \frac{\pi_{j+s,t+s}}{\pi_{j,t}} u_j\left(c_{j+s,t+s}, 1 - l_{j+s,t+s}\right), \quad \textbf{(A.1)}$$

subject to the budget constraint

$$(1+\tau_{c,t})c_{j,t} + s_{j,t} + \tau_j + \Upsilon_t = (1 - \tau_{\iota,t} - \tau_{l,t})\omega_j w_{j,t} l_{j,t} + \left(1 + r_t\left(1 - \tau_{k,t}\right)\right) s_{j-1,t-1} + \Gamma_{j,t}, \quad \textbf{(A.2)}$$

when working, whereas for the retired population ($j \geq \bar{J}$) it takes the form

$$(1+\tau_{c,t})c_{j,t} + s_{j,t} + \tau_j + \Upsilon_t = [1 + r_t(1-\tau_{k,t})]s_{j-1,t-1} + (1-\tau_{l,t})(b_{\iota,j,t}) + \Gamma_{j,t}, \quad \textbf{(A.3)}$$

where $b_{\iota,j,t}$ is the pension benefit for a person at age j at time t from system ι. Pension systems are indexed by ι, which corresponds to either Defined Contribution or Defined Benefit ($\iota \in \{\text{DB}, \text{DC}\}$). $\Gamma_{j,t}$ denotes bequests the cohort j receives at time t from agents of the same cohort who died at the end of $t-1$.

Solving, we obtain the final solution for consumption and labor supply (and thus instantaneous savings) for the working cohorts:

$$c_{j,t} = \frac{[1 + r_t(1-\tau_{k,t})]s_{j-1,t-1} - \tau_{j,t} - \Upsilon_t + (1 - \tau_{s,t} - \tau_{l,t})w_{j,t} + \Omega_{j,t} + \Gamma_{j,t}}{\frac{1}{\phi} + \frac{1}{\phi}\beta \sum_{s=1}^{\bar{J}-j-1} \delta^s \frac{\pi_{j+s,t+s}}{\pi_{j,t}} + \beta \sum_{s=\bar{J}-j}^{J-j} \delta^s \frac{\pi_{j+s,t+s}}{\pi_{j,t}}}, \quad \textbf{(A.4)}$$

$$l_{j,t} = 1 - \frac{1-\phi}{\phi} \frac{(1+\tau_{c,t})c_{j,t}}{w_{j,t}},$$

with

$$\Omega_{j,t} = \sum_{s=1}^{\bar{J}-j-1} \frac{(1-\tau_{s,t}-\tau_{l,t})w_{j+s,t+s} - \tau_{j+s,t+s} - \Upsilon_{t+s}}{\prod_{i=1}^{s}[1+r_{t+i}(1-\tau_{k,t+i})]},$$

$$\Gamma_{j,t} = \sum_{s=\bar{J}-j}^{J-j} \frac{b_{j+s,t+s} - \tau_{j+s,t+s} - \Upsilon_{t+s}}{\prod_{i=1}^{s}[1+r_{t+i}(1-\tau_{k,t+i})]}.$$

The numerator of equation (A.4) represents the current discounted value of the future lifetime income.