The Sooner The Better - The Welfare Effects of the Retirement Age Increase Under Various Pension Schemes[*]

Marcin Bielecki
University of Warsaw

Karolina Goraus[†]
University of Warsaw

Jan Hagemejer
National Bank of Poland
University of Warsaw

Joanna Tyrowicz
University of Warsaw
National Bank of Poland

First version: January, 2014
This version: May, 2014

Abstract

We evaluate the welfare and macroeconomic effects of increasing the retirement age in the context of population aging. In an overlapping generations framework we simulate the increase of the retirement age by seven years under different pension systems (defined benefit, notionally defined contribution and fully funded). We show that raising the retirement wage is universally welfare enhancing for all living and future cohorts, regardless of the pension system. Quantitatively, this policy intervention is able to counterweight the adverse macroeconomic consequences of aging. We test the validity of our findings in a population with lower pace of aging due to higher fertility. Finally, we show scope for further welfare gains if productivity is relatively high at old ages.

Key words: pension system, defined benefit, NDC, retirement age, pension system reform, welfare

JEL Codes: C68, E17, E25, J11, J24, H55, D72

[†]Corresponding author. E-mail: kgoraus@wne.uw.edu.pl.

1 Introduction

With the aging processes of populations, the ratio between the number of retirees and those of the working increases, which hazards the stability of pension systems. This problem is potentially most acute in the pay-as-you-go defined benefit (DB) systems, which are fairly common among advanced economies. Alternative schemes – such as notionally defined contribution (NDC) and fully funded (FDC) – rely more directly on actuarial fairness, which potentially limits the scope of adverse fiscal effects, but longevity substantially reduces the benefits, which too may call for policy intervention.

Indeed, the process of aging was present in the economic research as early as in the 1950s (Modigliani and Ando 1957) but it is the emergence of the overlapping generations literature in the late 1980s that gave momentum to the research in the field. Furthermore, late 1990s are the period when the first signs of demographic transition became visible in the advanced economies and even fairly simple numerical simulation studies were able to show considerable fiscal burden emerging from purely demographic trends. In the debate over the past three decades various policy options have been proposed. These include reduction in pension benefits, increases in taxes, facilitation of immigration as well as fertility and productivity policies, Aglietta et al. (2007), van Sonsbeek (2010). Among the most hotly debated is increasing the minimum eligibility age for retirement. Hviding and Marette (1998) compared the timing of various reforms' backlashes and conclude that increasing retirement age could potentially serve as most effective instant relief for public finances. Numerical simulations almost unequivocally show a considerable reduction in fiscal burden as well as an increase in the received pension benefits.

However, as pointed out by Kotlikoff and Summers (1981), numerical simulations are far from sufficient to analyze policy issues such as raising the retirement age. First, since they do not have any behavioral mechanisms, they are unable to capture the response to policy in terms of labor supply and savings. Indeed, such exercises implicitly assume that a considerable policy change leads to no behavioral change, which is highly unlikely. Second, saving behavior tends to be age-specific. Miles (1999) reviews the extensive evidence on the impact of aging on savings and capital accumulation, concluding that general equilibrium effects are likely to be large and need not be overlooked [1]. Third, even if fiscal and macroeconomic consequences of raising the minimum eligible retirement age were universally positive, this increase happens at the expense of leisure, which has important intrinsic value to the agents. Research that take no account of welfare may thus heavily mislead policy guidance.

Seminal contribution of Auerbach and Kotlikoff (1987) provides a broad and versatile framework for a general equilibrium with overlapping generations (OLG). The heterogeneity between cohorts helps to analyze the impact of the demographic change on the economy as well as to reliably model the effects of various pension system reforms, Boersch-Supan and Ludwig (2013), De Nardi et al. (1999). Indeed, comparisons of the two scenarios - the simulated *status quo* and an implemented or potential reform scenario - enable an assessment of both welfare and macroeconomic effects of pension system reforms, (Lindbeck and Persson 2003, Fehr 2009). Since all these models necessarily rely on the concept of utility, welfare is directly conceptualized and can easily be compared between alternative scenarios, (Breyer 1989, Feldstein 1995).

Numerous studies apply OLG models to analyze the overall efficiency of postponing the labor market exit. Two main approaches can be distinguished among these studies. First strand of literature directly assesses the macroeconomic and welfare effects of the change

---

[1]See also Jimeno et al. (2008) for more recent survey of different approaches used to analyse the effects of aging on the sustainablity of social security systems

in exogenous retirement age through comparison to the baseline scenario of no pension system reform, e.g. Auerbach et al. (1989), Hviding and Marette (1998), Fehr (2000), Boersch-Supan and Ludwig (2010), Vogel et al. (2012). Numerous papers also challenge the effectiveness of increasing the retirement age by estimating the effects of other reform proposals, cfr. Auerbach et al. (1989), Hviding and Marette (1998), Fehr (2000).

In the second group of papers retirement age is determined endogenously in the model. They aim to observe if demographic change or policy change may endogenously induce a change in behavior leading to sufficient postponement of labor market exit. If agents/households may freely choose the moment of exit (in order to maximize their lifetime utility), the *de iure* retirement age may be evaluated and thus amended to reflect voters' preference, cfr. Gruber and Wise (2007), Galasso (2008), Heijdra and Romp (2009). Thus the positive or negative effect of raising the retirement age can be indirectly measured: if the optimally chosen retirement age reveals to be higher than the minimum eligibility age, postponing labor market exit is welfare enhancing. For example, evidence provided by Galasso (2008) suggests that in aging societies – such as France, Italy, the UK, and the USA – median voter would raise the retirement age.

Welfare assessment of postponing the labor market exit is inherently ambiguous. Reducing leisure has a direct welfare deteriorating effect. On the other hand, increasing retirement age potentially allows for raising the old-age consumption (Galasso 2008). In addition, alleviating the fiscal burden may lead to higher general consumption (Boersch-Supan 2013). However, the effect of prolonging the working life and reducing leisure may be suppressed by withdrawal of labor supply or within-household substitution (Boersch-Supan and Ludwig 2013). Last but not least, lower taxation of younger generations may translate into higher productive capacity (Boersch-Supan 2013). Furthermore, the impact of pension reform may differ substantially between generations as well as depend on the existing regulations and behavioral response to the policy change (Fehr 2000). Vast literature simulated the effects of reforming the initial DB scheme (Auerbach et al. 1989, Hviding and Marette 1998), whereas the effects of reforming the DC schemes are less explored (Beetsma and Bucciol 2011).

However, the effects of the increase in retirement age were mostly analyzed under DB pension system design (Boersch-Supan and Ludwig 2013, Vogel et al. 2012). Indeed, Fenge and Pestieau (2005) as well Fehr (2000) underlined that there may be substantial differences in efficiency gains or losses from the pension reform depending on the linkage between contributions and benefits. For example, Auerbach et al. (1989) allow the adjustment to occur via lower contribution rates, which immediately negatively impacts older generations (little welfare gain from lower contributions, large welfare loss from longer working period).

Given this state of the literature, we aim to contribute in three major ways. First, we actually *compare the welfare and macroeconomic effects* of raising the minimum eligibility age under three of the most popular pension schemes: defined benefit (DB), notionally defined contribution (NDC) and fully funded defined contribution (FDC). We follow Nishiyama and Smetters (2007) and introduce a Lump-Sum Redistribution Authority that introduce compensating transfers between the losers and beneficiaries of the reform. Therefore, it is possible to assess the overall efficiency of the analyzed changes in each of the pension systems. Second, we analyze *different demographic scenarios*: rapid demographic change, similar to many European economies (decreasing fertility and raising longevity) and more stable demographic transition (with stable fertility accompanied by a gradual increase in longevity). [2] Our demographics is calibrated to the projection for Poland and the two

---

[2]In fact, the evidence on the effects of increasing retirement age under stable demographics is scarce (Galasso 2008), whereas it is a relevant dimension given the steadily growing life expectancy and differentiated fertility evolutions across advanced economies.

scenarios we construct are: (i) decreasing mortality and lowering fertility, which reflects the demographic projection for Poland; (ii) fertility kept constant at levels from 2010 and decreasing mortality, as described in the projection.

Third, we provide a *precise analysis of the labor market effects*. Although various studies assume exogenous labor supply (Galasso 2008, Heijdra and Romp 2009, Hviding and Marette 1998, Fougere and Merette 1999), clearly labor supply adjustments will occur in an effect of pension system reforms (Boersch-Supan et al. 2006, Ludwig 2005, Ludwig et al. 2007, Bassi 2008, Boersch-Supan and Ludwig 2013). In fact, the analysis of the labor supply response is far from trivial and hinges significantly upon the choice of the utility fuction. Typically, the literature differentiates between intensive (hours) and extensive (years) margins. However, starting from Auerbach and Kotlikoff (1987), CES utility function is often assumed. In the OLG framework this otherwise useful form has some adverse consequences. Namely, the supply of labor depends on consumption, and the adjustment after the increasing retirement age is influenced by the wealth effect, which makes it impossible to precisely distinguish between changes in the labor supply on the intensive and extensive margin[3]. We apply the Greenwood-Hercowitz-Huffman (1988) utility function, which makes labor supply decisions fully independent of the intertemporal consumption-savings choice (Furlanetto and Seneca 2014). In fact, labor supply mainly responds to changes in wages. As proven by Heer et al. (2014), GHH preferences eliminate the problem of wealth effects on labor supply (assets accumulation with age additionally reduces labor supply in older ages). With the original GHH preferences leisure and retirement can be perceived as a normal goods (Diamond and Barr 2006, Ascari and Rankin 2007). Moreover, it has been forcefully argued that labor supply response to tax shocks is amplified under standard CES utility function, which may lead to unrealistically high estimates of the labor market effects of fiscal policy, cfr. Schmitt-Grohe and Uribe (2003), Jaimovich and Rebelo (2009), Monacelli and Perotti (2008), Schmitt-Grohe and Uribe (2012), Nakamura and Steinsson (2014). On the downside, as argued by (Blanchard 1985), with some specifications negative labor supply is consistent with GHH, but adequate parametrization is able to eliminate this shortcoming.

Our paper hopes to answer a number of policy relevant questions. First, we inquire if macroeconomic and welfare effects of raising the minimum eligible retirement age are stronger or weaker depending on the pension system *ceteris paribus*. We find that although quantitatively the effects may differ, such policy is universally welfare enhancing for all cohorts, irrespectively of the pension system. In our setting wealth effects on the the supply are eliminated, so we isolate the intensive margin adjustment. Second, we investigate if this result could be reversed under more stable demographics and the answer given by our framework is negative. More specifically, even if demographic change is slower and smaller than the one faced by many advanced economies, the welfare and macroeconomic gains from longer work remain essentially unaffected. Thirdly, we ask what is the scope for additional macroeconomic and welfare gains if skills/productivity of the population increase. In fact, whereas fertility policies remain only selectively effective, longevity is a fairly universal phenomenon, implying an increased duration of life in health. Also, educational attainment is systematically increasing in the advanced economies, which suggests that age-productivity patterns may seize to decrease in the older ages.

The paper is structured as follows. The next section introduces the model. In section 3 we discuss the calibration and the analyzed demographic scenarios. Section 4 discusses the results, with particular emphasis on the cohort analysis of the welfare effects. This section comprises also the robustness checks. The last section concludes with policy recommenda-

---

[3]CES form utility function is used among others by Boersch-Supan et al. (2006), Ludwig (2005), Ludwig et al. (2007), Bassi (2008), Boersch-Supan and Ludwig (2013)

tions.

2 The Model

The simulation model is a dynamic deterministic overlapping generations model with three sectors: households, firms and the government running the retirement scheme. The core idea of the model is fairly standard in the literature. In the remainder of this section we want to primarily emphasize the departure points and their effects on the model.

2.1 Households

Households derive utility from consumption c and leisure $(1 - l)$. Each household consists of a single person who is born at age 20, which we denote as $j = 1$ in the model and lives up to its 100th birthday. Therefore, at each time period we have a total of $J = 80$ overlapping generations households alive, differentiated by age $j = 1, 2, \ldots, J$.

The objective function of a household is to maximize its remaining lifetime utility:

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

where δ is the time discounting factor and $\pi_{j,t}$ denotes the unconditional probability of a household of having survived from birth to age j at time period t. The households know their survival probabilities with certainty. To simplify, we assume that the survival probability beyond $j = J$ is exactly 0.

As discussed earlier, we employ the GHH utility function in the following form:

$$u\left(c_{j,t}, l_{j,t}\right) = \frac{1}{1-\theta}\left[\left(c_{j,t} - \psi_t \frac{l_{j,t}^{1+\xi}}{1+\xi}\right)^{1-\theta} - 1\right], \tag{2}$$

where ξ is the inverse of the Frisch labor elasticity and ψ_t is the labor disutility parameter. Since the model with constant disutility of labor would be inconsistent with the long-run growth, we assume that technological progress increases the utility of leisure, i.e. $\psi_t = \psi \cdot z_t$, where z_t denotes technological improvement and ψ is a constant. This choice of the utility function makes labor supply decisions independent of wealth effect. In fact, the intensive margin adjustment happens entirely in response to wage changes.

The households supply labor $l_{j,t}$ as long as they do not reach the retirement age, $\bar{J}_t$. Until they do, they pay taxes on labor, τ_t^l, and bear the cost of the retirement scheme as an additional tax levied on labor, τ^ι. There is also a *per capita* tax Υ_t, which allows to capture the burden of other taxes which are not explicitly modeled. We allow for the household labor productivity ω to potentially vary with age j, resulting in the gross labor income of $\omega_j \cdot w_t \cdot l_{j,t}$. After they retire, households pay taxes on retirement benefits $b_{j,t}$. We assume that the labor and retirement income are taxed at the same rate[4], τ_t^l. Both retired and working agents' consumption is burdened by the consumption tax, τ^c, and their capital income r_t from savings $s_{j,t}$ is burdened by the capital income tax, τ^k. In the response to changing fiscal burden due to the demographic change, we will allow τ_t^l to vary with time, whereas the policy change will consist of $\bar{J}_t$ increases. Other taxes as well as general regulatory framework will be held constant throughout the simulations.

---

[4]This choice is dictated by the legal regulations in Poland.

In order to compare the welfare in a result of retirement age changes, similar to Nishiyama and Smetters (2007), we introduce the possibility of intergenerational redistribution performed by a Lump Sum Redistribution Authority (henceforth LSRA) which may levy a lump-sum tax/transfer equal for all cohorts at a given time period t, $\tau_{j,t}$. The LSRA allocates the tax/transfer to each cohort comparing the utility cohort j would have had in the no-change scenario and the one cohort j has in the analyzed policy scenario. The tax/transfer is computed as a consumption equivalence based on the difference in the utilities.

The budget constraint at time t of a working ($j < \bar{J}$) household is given by:

$$(1 + \tau^c)c_{j,t} + s_{j,t} + \tau_{j,t} + \Upsilon_t = (1 - \tau^\iota - \tau^l_t)\omega_j w_t l_{j,t} + \left[1 + (1 - \tau^k)r_t\right] s_{j-1,t-1} + beq_{j,t}, \quad (3)$$

where $beq_{j,t}$ denotes the bequests the cohort j receives at time t from the agents deceased at the end of time period $t - 1$ (bequests are distributed uniformly across cohorts). The budget constraint at time t of a retired ($j \geq \bar{J}$) household is given by:

$$(1 + \tau^c)c_{j,t} + s_{j,t} + \tau_{j,t} + \Upsilon_t = (1 - \tau^l_t)b^\iota_{j,t} + \left[1 + (1 - \tau^k)r_t\right] s_{j-1,t-1} + beq_{j,t}, \quad (4)$$

where $b^\iota_{j,t}$ denotes pension benefit for person at age j in time t. Pension systems are indexed by ι, which corresponds to either funded defined contribution (FDC), notionally defined contribution (NDC) or also pay-as-you-go but a defined benefit scheme, DB, i.e. $\iota \in \{FDC, NDC, DB\}$.

2.2 Firms

A single perfectly competitive representative firm produces a multi-purpose good according to the standard Cobb-Douglas production function. Output in time t is given by $Y_t = K_t^\alpha (z_t L_t)^{1-\alpha}$, where K_t is the aggregate capital stock in the economy, and L_t is the aggregate labor supply in the economy. The labor-augmenting technology grows at an exogenous rate of z_t.

Standard firm optimization implies the average market wage $w_t = (1 - \alpha) K_t^\alpha z_t^{1-\alpha} L_t^{-\alpha}$ and interest rate $r_t^k = \alpha K_t^{\alpha-1} (z_t L_t)^{1-\alpha} - d$, where d stands for depreciation. Note that since all factors of production are rewarded according to their marginal productivity, the per hour wage of a j-aged household $w_{j,t} = \omega_j \cdot w_t$.

2.3 Government and retirement insurance schemes

The government runs (one of the) pension schemes and collects taxes. In addition the government spends a fixed amount on necessary yet unproductive consumption. The pension systems we analyze differ in terms of cash flow and in as far as the rules for computing the pensions and contribution rates are concerned. Namely, defined benefit (DB) is of a pay-as-you-go nature, which implies that contemporaneously collected contributions serve the purpose of current benefits payments. The pension is computed as a fixed percentage of a last wage. Conversely, in defined contribution schemes, pensions are computed in an actuarially fair manner, i.e. individuals receive in the form of pension an equivalent of their lifetime (accrued) contributions. In the notionally defined contribution (NDC), there are no actual savings, though, because this is a pay-as-you-go system. In the funded defined contribution (FDC), contributions add up to private savings in the capital accumulation. Below we discuss in detail the characteristics of each pension scheme.

The defined benefit pension system is constructed by imposing a mandatory exogenous contribution rate τ^{DB} and an exogenous replacement rate ρ. The relationship between the first retirement benefit and households' wages is given by: $b_{j,t}^{DB} = \rho \tilde{w}_{j,t}$, where $\tilde{w}_{j,t}$ is an average wage of a retiree for her last 10 years of working[5]. Subsequent benefits are indexed by the formula $1 + r_t^{DB}$, where r^{DB} denotes the indexation rate on the DB scheme. This indexation rate is coincidental with the indexation rate in the NDC scheme, which we derive below.

Since there is no guarantee that such a system will be balanced, the government is forced to balance the inflows and outflows in the scheme, captured by the $subsidy_t^{DB}$ variable. The system collects contributions from the working and pays to the retired:

$$\sum_{j=\bar{J}}^{J} N_{j,t} b_{j,t}^{DB} = \tau_t^{DB} \sum_{j=1}^{\bar{J}-1} w_{j,t} l_{j,t} N_{j,t} + subsidy_t^{DB} \tag{5}$$

In contrast to the DB system, both NDC and FDC systems are by construction actuarially fair, i.e. the expected benefits paid over the retirement period equal the sum of contributions. The first retirement benefit, indexed in the following years by $1 + r_t^{NDC}$, is given by:

$$b_{\bar{J},t}^{NDC} = \frac{\sum_{s=1}^{\bar{J}-1} \left[\prod_{m=1}^{s} \left(1 + r_{t-j+m-1}^{NDC} \right) \right] \tau_{t-j+s-1}^{NDC} w_{s,t-j+s-1} l_{s,t-j+s-1}}{\prod_{s=\bar{J}}^{J} \pi_{s,t}}, \tag{6}$$

where r^{NDC} denotes the indexation rate on the NDC scheme, defined by legislation as a rate of growth in the aggregate payroll:

$$r_t^{NDC} = \frac{\sum_{j=1}^{J} \left(w_{j,t} l_{j,t} N_{j,t} - w_{j,t-1} l_{j,t-1} N_{j,t-1} \right)}{\sum_{j=1}^{J} w_{j,t-1} l_{j,t-1} N_{j,t-1}} \tag{7}$$

Although the NDC scheme is actuarially fair, the current contributions are contemporaneously paid out in the form of benefits to the retirees and the changes in the demographics may lead to the imbalance between current contributions and benefit payments. Thus, as in the case of the DB scheme, the government makes a transfer to ensure the equality between the inflows and outflows:

$$\sum_{j=\bar{J}}^{J} N_{j,t} b_{j,t}^{NDC} = \tau_t^{NDC} \sum_{j=1}^{\bar{J}-1} w_{j,t} l_{j,t} N_{j,t} + subsidy_t^{NDC} \tag{8}$$

Finally, the first benefits under the FDC scheme, indexed in the following years by $1 + r_t^{FDC}$ are computed analogously to the ones obtained for the NDC case:

$$b_{\bar{J},t}^{FDC} = \frac{\sum_{s=1}^{\bar{J}-1} \left[\prod_{m=1}^{s} \left(1 + r_{t-j+m-1}^{FDC} \right) \right] \tau_{t-j+s-1}^{FDC} w_{s,t-j+s-1} l_{s,t-j+s-1}}{\prod_{s=\bar{J}}^{J} \pi_{s,t}}, \tag{9}$$

where r^{FDC} denotes the return on investment under the FDC scheme. Since under the FDC scheme current benefit payments are financed by past contributions, the system runs a cashflow surplus by construction, so there is no need for government subsidies.

We assume that the FDC allocates its contributors' assets into a composite asset consisting of productive capital and government debt, identical to the portfolio choice of individual households. Since we do not have risk in our model and the interest rate on

---

[5]Following the Polish legislation.

government debt is assumed to be lower than on capital, we need to force the households to buy government debt. We assume demand for government debt to be inelastic (households purchase the entire stock of outstanding bonds). Households allocate the remainder of the savings into productive capital. Obligatory savings collected in the FDC scheme are invested according to the same rules as private voluntary savings. Thus, the rate of return on the composite asset is an average of the interest rate on capital r^k and government debt r^G, weighted by their shares in the portfolio.

In addition to balancing the retirement schemes, the government collects taxes on earnings, interest payments and consumption, and spends a fixed share of GDP on government consumption which does not impact the households' utility. Additionally, the government services any outstanding debt.

$$
T_t = \tau_t^l \left(\sum_{j=1}^{J} (w_{j,t} l_{j,t} + b_{j,t}) N_{j,t} \right) + \tau^c \left(\sum_{j=1}^{J} c_{j,t} N_{j,t} \right) + \tau^k \left(\sum_{j=1}^{J} r_t s_{j-1,t-1} N_{j,t} \right) \quad (10)
$$

$$
G_t = T_t + (D_t - D_{t-1}) + \Upsilon_t N_t - subsidy_t^\iota - r_t^G D_{t-1}, \quad (11)
$$

with $G_t = \gamma_G Y_t$ and where N_t is the aggregate population. We set the level of debt to GDP ratio at 45%, the level close to the one observed in Poland in 1999.

2.4 Market clearing and equilibrium

The goods market clearing condition is given by:

$$
\sum_{j=1}^{J} c_{j,t} N_{j,t} + K_{t+1} + G_t = Y_t + (1 - d) K_t \quad (12)
$$

Implicitly, we assume that at each time period the prices for capital and labor adjust such that the demand from the consumers, producers and government is met. This requires that the capital and labor markets also clear:

$$
L_t = \sum_{j=1}^{\bar{J}-1} \omega_j l_{j,t} N_{j,t} \quad \text{and} \quad K_{t+1} = (1 - d) K_t - (D_t - D_{t-1}) + \sum_{j=1}^{J} \hat{s}_{j,t} N_{j,t}, \quad (13)
$$

where $\hat{s}_{j,t}$ denotes private savings $s_{j,t}$ as well as accrued contributions in the FDC scheme. An equilibrium is thus an allocation $\{(c_{1,t}, \ldots, c_{J,t}), (s_{1,t}, \ldots, s_{J,t}), (l_{1,t}, \ldots, l_{J,t}), K_t, L_t, Y_t\}_{t=0}^{\infty}$ and prices $\{w_t, r_t\}_{t=0}^{\infty}$ such that

- for all $t \in \{0, 1, \ldots\}$ and for all $j \in \{1, 2, \ldots, J\}$ the allocation $[(c_{j,t}, \ldots, c_{J,t+J-j}), (s_{j,t}, \ldots, s_{J,t+J-j}), (l_{j,t}, \ldots, l_{J,t+J-j})]$ solves the problem of a j-aged agent for all t given prices;

- (K_t, L_t, Y_t) solves the firms' problem;

- government sector is balanced;

- markets clear.

8

2.5 Solution procedure

The model is solved by finding the transition path between the initial and final steady states. First, we compute these steady states. We set the length of the transition path to encompass all cohorts that are subject to the changing demographic environment and at least one cohort that lives its whole life in the final steady state. Usually, it suffices that the length of the path is at least the length of the demographic transition plus the maximal lifespan of a household. In our analysis, we use a 60 years demographic projection which added to the maximal lifespan J of 80 yields 140. In order to err on the safe side, we set the length of the path to 250 periods.

The solution procedure follows the Gauss-Seidel method. In the steady states, we start with guesses on capital which is enough to compute aggregates in the economy. The households gifted with perfect foresight take them as given and produce their optimal decision rules, which are then aggregated to produce a new guess in the next iteration. The procedure is repeated until the difference between the initial aggregate capital and the capital aggregated from household savings are numerically indiscernible.

Along the transition path, we produce a path of guessed aggregate variables basing on the results of the initial and final steady states. The solution procedure is then analogous to the one used to compute the steady states.

3 Calibration and scenarios

The calibration of our model bases on the actual macro- and micro-evidence for the Polish economy, as well as on the projections for years 2010–2060 by the EU's Economic Policy Committee Working Group on Ageing Populations and Sustainability (henceforth AWG). Using our framework, we analyze the effects of three different pension schemes, although only one of those was actually present in the Polish economy in 1999 (pay-as-you-go defined benefit scheme). Our calibration is thus done in two stages. First, we find the so-called deep parameters which allow the model to replicate Polish economy of 1999 with DB system. We then keep the deep parameters fixed across the pension schemes. We have decided to keep the pension contribution tax rate to be constant across schemes, regardless of the resulting replacement rate[6]. The remainder of this section describes in detail the calibration procedure and outlines the key characteristics of analyzed scenarios.

3.1 Calibration of the deep parameters

As is common in the macroeconomic literature, we set the capital share of income at the level of 31%. We also set the yearly depreciation rate on aggregate capital to amount 5.5%, which is in the ballpark of the empirical estimates. Following Nishiyama and Smetters (2007), we set the interest rate in our model to be around 6.25%, which is supposed to reflect the average yearly return from mixed risk-free and risky assets portfolio in the developed countries. Given the depreciation rate we look for the discounting factor δ that allows us to match both the aforementioned interest rate as well as the investment share in the GDP at the level of app. 23%[7].

---

[6]Please note that the DB scheme does not require actuarial fairness between the sum of contributions and resulting pension benefits. As such, the replacement rate in most of the European countries was set on a higher level than implied by the contribution rates.

[7]The value of 23% is obtained by taking the averages of Gross Fixed Capital Formation statistic for Poland for years 1997-2001. The arithmetic and the geometric averages yield the values of 23.06% and 23.02%, respectively.

In order to simplify the derivation of our results, we chose the relative risk aversion parameter θ equal to 1, which is common in the macroeconomic literature. The GHH utility parameters were chosen to reflect the 56.8% labor market participation rate as observed in Poland in 1999. The ξ parameter was set to yield the same Frisch elasticity as in a standard Cobb-Douglas type utility function calibrated to produce said 56.8% participation rate. The labor disutility parameter, ψ, was chosen to generate the desired labor market participation rate in the GHH case. Below we provide the results of calibration for two different age-productivity profiles ω – one flat and one resulting from the Deaton (1997) decomposition.

Table 1: Calibrated technology and preference parameters

Parameters		ω – flat	ω – Deaton (1997)
Technology			
α	capital share of income	0.31	0.31
d	depreciation rate	0.055	0.055
Preferences			
δ	discounting factor	0.99175	1.00693
θ	relative risk aversion	1	1
ξ	Frisch elasticity (inverse)	3.846	4.101
ψ	labour disutility	7.59	4.64
Target statistics			
r	interest rate	0.0625	0.0625
$\Delta k/y$	investment rate	0.23	0.23

The rate of the labor-augmenting productivity growth of the economy is borrowed from the AWG's projection, which assumes effective convergence across European economies to a uniform 1.7% exogenous technological growth rate as of 2030 and a gradual approaching of this value from actual higher rates between 2000 and 2030. This assumption is the same in the baseline and in the reform scenarios, which implies it only has marginal bearing on the results.

Figure 1: AWG's projection of productivity growth
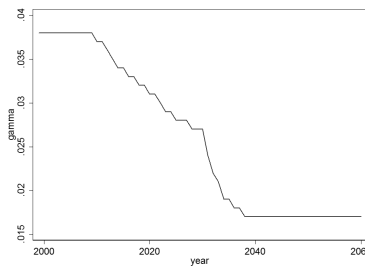
3.2 Calibration of taxes and pension system parameters

We set the tax system characteristics to match the actual legal situation in Poland as closely as only feasible within our model. We calibrate the marginal tax rates on labor and consumption to the actual effective tax rates, resulting in an 11% tax rate on consumption and labor income, a value significantly lower than the *de iure* tax rates. Capital income tax was set to 19%, which reflects the fact that *de iure* and effective tax rates are roughly equivalent. Reflecting the long-term trends, the pure government spending share in GDP

γ^G was set to 20%. Data implies that over the 1995-2005 period the government paid approximately 45% of the commercial market interest rate. This ratio was decreasing over time, and is expected to reach the level observed in developed economies of approximately one third. Thus, we set the bonds interest rate in relation to the households' portfolio interest rate to be equal $r^G = 0.33 \cdot r$. Finally, the lump-sum tax Υ was set to reflect the budget deficit of app. 3%, as has been the case over the past decade. Throughout the simulations the Υ rate in GDP is held constant and so is γ^G. These parameters are the same in both baseline and reform scenarios, so whatever their choice, they could only marginally influence the findings.

In 1999 Poland had a defined benefit pay-as-you-go pension system. We calibrate the exogenous replacement rate ρ to match the observed aggregate pension benefits share in GDP, which amounted to 5%. Consequently, we set the contribution tax rate τ^{DB} to the level that results in an observed ratio of pension system subsidies to GDP of 1.5%. In order to facilitate comparison across various pension schemes, we keep the obtained contribution tax rate at the same level for NDC and FDC schemes.

Table 2: Calibrated tax rates and pension system parameters

Parameters		ω – flat	ω – Deaton (1997)
Taxes and government			
τ^c	consumption tax	0.11	0.11
τ^l	labor income tax	0.11	0.11
τ^k	capital income tax	0.19	0.19
γ^G	government spending / GDP	0.2	0.2
Pension systems			
ρ	exogenous replacement rate	0.25	0.15
τ^ι	contribution rate	0.61	0.61
Target statistics			
	budget deficit (as % of GDP)	0.03	0.03
	aggregate benefits (as % of GDP)	0.05	0.05
	$subsidy^{DB}$ (as % of GDP)	0.015	0.015

3.3 Demographic scenarios

Both of our demographic scenarios are based on the AWG's demographic projection for Poland for years 2010–2060. There is a variety of demographic projections available, but most of them divide the population into five-year age groups. This shortcoming of the data ushers important methodological challenge to the model, cfr. Berger et al. (2009) and Keuschnigg et al. (2012). Fortunately, AWG's projections are based on the computations of the national statistical offices of the Member States in one-year intervals and age groups. This projection contains forecasts on the number of births as well as mortality rates. In order to obtain our first steady state, we compute the stationary distribution of the population basing on the 2010 mortality rates.

To distinguish between different aspects of the current demographic transition, we construct two scenarios. In the first one we replicate the projection of the AWG starting from the computed stationary distribution. This scenario consists of an increasing life duration and a decreasing number of births[8]. Naturally, this projection puts a double

---

[8]Please note that here we are talking about actual, real-world births, and not of the appearance of 20-year-olds in the model.

strain on the pension system. Given that the Polish demographic projection is relatively acute when compared to other EU Member States, we also produce a second, milder scenario. Namely, we allow for the mortality rates to change according to the projection but we hold the number of births constant at the level corresponding to the one projected for 2010.

Given this approach, the demographic structure is at any time fully described by the initial births and the survival probabilities. In particular, we fix the survival probabilities and births after 2060 to the projection for that year. Since in our model births are a black-box and their number does not depend on any model-related characteristic, the population reaches its second steady state as fast as in 2160.

Figure 2: Demographic scenarios

(a) survival $\pi_{j=20}^{\bar{J}=60}$ (b) Total population, ages 20-99   (c) Population of 20-year-olds
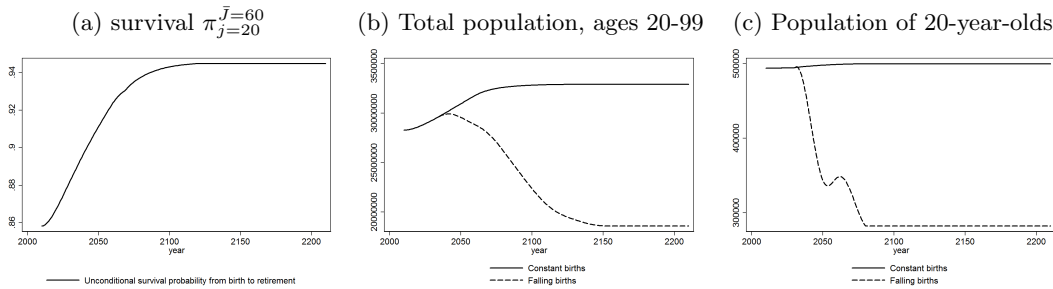
3.4 Age-productivity profile

Finally, as a robustness check, we consider two separate age-productivity profiles. The first one assumes that the workers' productivity is independent of their age and is thus normalized to 1 for all ages. The second takes into the account the possibility that productivity is a function of age. The productivity across life-cycle is a subject of a sizable body of literature. A number of the microeconometric studies find an inverted U-shaped pattern[9].

However, it is empirically challenging to separate age effects from cohort and year effects. Indeed, many studies that are able to isolate the age effects suggest a flat or even moderately increasing age-productivity pattern. For example, Boersch-Supan and Weiss (2011) show that controlling for cohort effects and self-selection makes the age-productivity relation fairly flat or - if anything - slightly increasing until the age of 65. We are not aware of any studies similar to Boersch-Supan and Weiss (2011) for a transition economy like Poland. Therefore, we use Deaton (1997) decomposition to isolate the age effects using 16 years of Polish Labor Force Survey data[10]. This decomposition, after standardization, yields the pattern depicted in Figure 3a.

In fact, studies have confirmed the causal link between productivity (skills) and the willingness to pospone the retirement age. For example, Kristensen (2012) finds that raising the skills of the elderly workers translates to later labor market exit even post the eligibility age. Although these effects typically are not quantitatively large, they are statistically significant, Stenberg and Westerlund (2013), Picchio and van Ours (2013).

---

[9]See Skirbekk (2004) as well as a special issue of Labor Economics (volume 22, 2013).

[10]For simplicity we only implement age-dependent differences in productivity via weighting the age-dependent labor inputs, however more advanced methods are already present in the literature, see Guest (2007), Fougere et al. (2007).

Figure 3: Alternative age-productivity pattern and retirement age path

(a) Deaton (1997) productivity profile

(b) Change in the retirement age
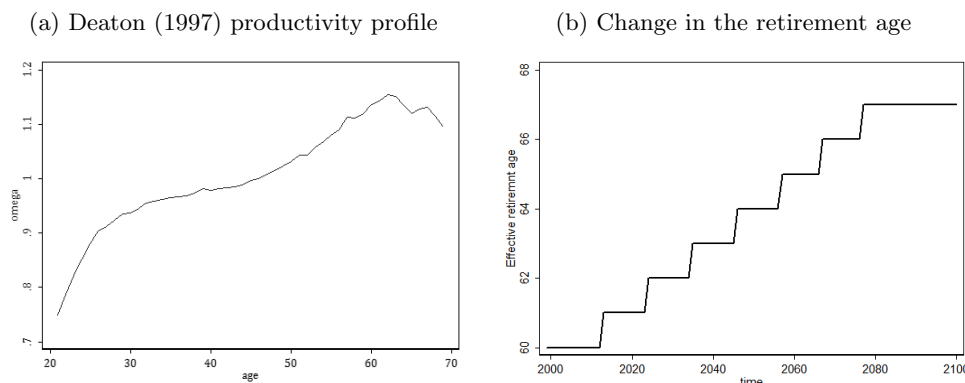
3.5 The reform scenario

We consider one reform scenario that consists of an increase in the eligible retirement age. Since in our framework individual labor productivity is set to zero for all $j > \bar{J}$, the eligibility age is the effective retirement age in the model. The *de iure* retirement age was 60 for women and 65 for men in 1999. However, the effective exit age was substantially lower, partly due to a number of additional pre-pension benefits available to many professional groups and partly due to other social assistance instruments targeting easing of the restructuring for elderly generations in the beginning of the transition from a centrally planned to a market economy.

To reflect this empirical regularity, the retirement age in the model is much lower until 2010 than the *de iure* retirement age, as depicted in Figure 3b. As of 2010 we assume that the retirement age is gradually increased until it reaches 67 in 2060. In fact, this pattern is similar to a policy implemented by the Polish government in 2013, which assumes a stepwise increase of the retirement age for both men and women to 67. The reform assumes women reaching 67 year threshold in 2040, but since effective retirement age typically falls short of the legal one, we allow the path to be somewhat flatter than the one previewed by the law.

3.6 Welfare comparisons

The welfare assessment of the reforms is performed by employing the Lump Sum Redistribution Authority mechanism. This procedure is performed in two steps. First, we compute the consumption equivalent for each cohort[11], including those living in the initial steady state. Second, we emulate the operation of levying lump sum taxes on winners and remunerating the losers so that the welfare change of the reform is exactly zero. If the present value of net transfers is negative, then the reform can be made Pareto improving by redistributing the remainder across all cohorts.

4 Results

This section reports the results of the baseline simulation with a fixed retirement age at a level equal to the effective value for 1999. In fact, we report results for three baseline

---

[11]In our case, this involves finding a cohort-specific compensating variation μ so that $U(\{c_j\}_{j=1}^J, \{l_j\}_{j=1}^J) = U(\{(1+\mu)c_j'\}_{j=1}^J, \{l_j'\}_{j=1}^J)$, where the variables with $'$ denote the after-reform ones.
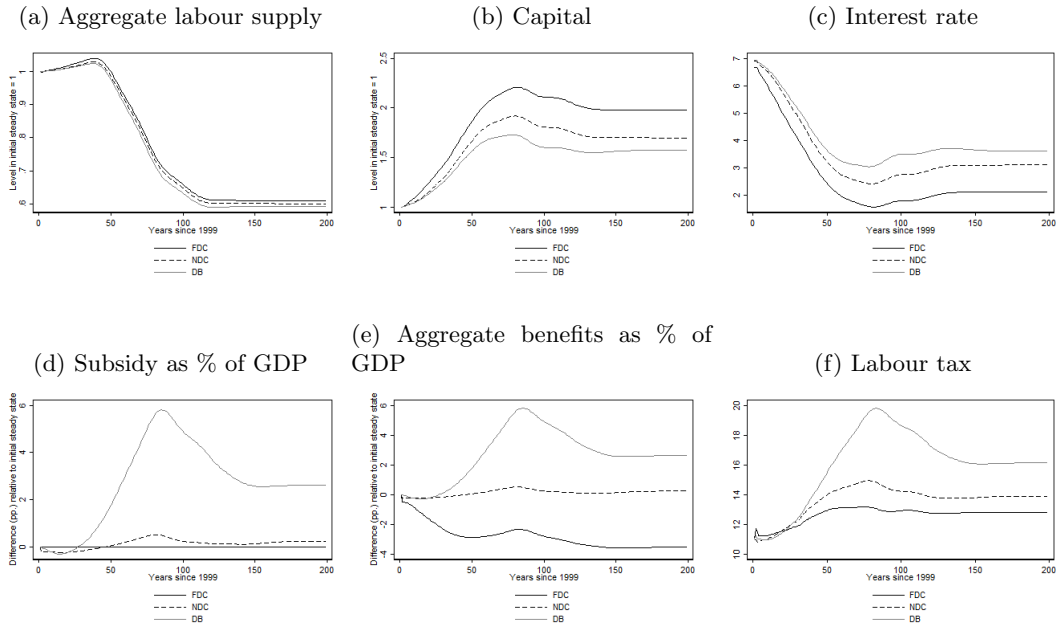
simulations, one for each of the pension system schemes: DB, NDC and FDC. We subsequently move in section 4.2 to analyzing the effects of the same policy change - a gradual increase in the minimum eligibility retirement age - under these three pension schemes. In section 4.3 we show the results for a milder demographic change and with an alternative specification for the age-productivity profile.

4.1 The baseline simulation

In the baseline scenario the demographic profile includes both decreasing mortality and fertility rates. We run the transition paths of a demographic change and decreasing labor productivity in three different pension system schemes: DB, NDC and FDC. In the initial steady state the macroeconomic variables are calibrated to that of the economy of Poland and the contribution rates to the pension system pillars are fixed across the pension schemes at the level yielding the target statistics observed under the DB scheme in 1999.

The three pension systems will generate different transition paths under the same assumptions on productivity and demographics. These are summarized in Figure 4. The long run capital stock accumulation is the highest under FDC pension system. Since capital directly translates to GDP (per effective unit of labor), output is also the highest under FDC. The supply of savings leads to a higher accumulation of capital. This subsequently leads to a long-run decrease of the interest rates. In fact, with the FDC this decrease is so vast, that temporarily economy becomes dynamically inefficient.

Figure 4: The baseline with flat productivity profile and decreasing fertility rates

(a) Aggregate labour supply
(b) Capital
(c) Interest rate
(d) Subsidy as % of GDP
(e) Aggregate benefits as % of GDP
(f) Labour tax

Labor supply changes are mostly driven by changes in the population. Since the number of people retired goes up in time, the burden to the working population that is caused by the DB pay-as-you-go schemes is high. In fact, under DB the deficit in the pension system (budget subsidy) goes up by about 4.5 pp. of GDP on the transition path to stabilize on the level higher by 2 pp. of GDP than in the initial steady state. The NDC system generates a surplus, since despite the demographic change, still somewhat more people contribute to the pension system than collect the benefits. FDC is by construction completely neutral to government budget.

14

Given the behavior of the interest rates, NDC scheme offers – at least temporarily – indexation rates higher than the rates of return in the FDC scheme. Consequently, the pensions grow in the NDC, whereas they decrease in FDC. Clearly, pensions increase most in the DB scheme. We express pension expenditure as a share of GDP, to facilitate the analysis along the transition path. Figure 4e depicts the deviation from the initial steady state in pp. In fact, population aging leads to a transitory increase in the aggregate annual pension expenditure by roughly 6pp in GDP share, relative to the original steady state. In the final steady state the expenditure is app. 3.5pp higher in terms of GDP share, when compared to the original steady state. This constitutes a more than 60% increase.

As a result of pensions growth, in the pay-as-you-go pension systems we observe a gradual increase of the labor tax which is used to finance the deficit in the pension system (subsidy required from the government budget to balance the pension system). Under NDC the increase is roughly half of the one required under DB due to decreasing effective replacement rates in the former system. With the self-financing of the FDC system, the tax rate is kept roughly stable. In fact, given constant share of government consumption and Υ in GDP, the increase in the labor tax observed in the baseline FDC scenario reflects the change in the labor share in this economy, that occurs solely due to aging and related general equilibrium effects.

4.2 The effects of raising the retirement age

The welfare effects of raising the retirement age are conceptually an ambiguity. On the one hand, given the baseline results, one would expect such policy reform to substantially increase consumption *via* lower taxes and higher benefits upon retirement. On the other hand, the reform substantially reduces leisure, and consequently, welfare. Given these opposing effects, the overall outcome remains an empirical question. The results of the comparison of pre- and post-reform utility levels (expressed in consumption equivalent terms) are depicted in Figure 5. In fact, all cohorts universally gain from the reform, although gains are largest for the future cohorts and lowest for the elderly at the moment of the reform.

Figure 5: Welfare effects of the reform, in consumption equivalent terms

(a) DB   (b) NDC   (c) FDC
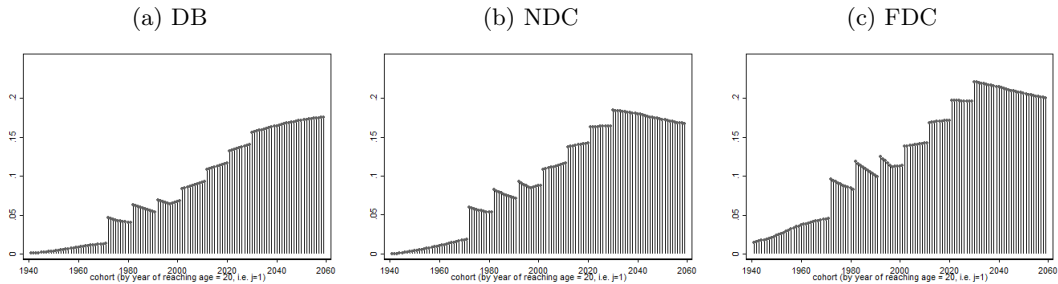
The consumption equivalent effect of the increase in retirement age under the baseline assumptions on demographics and productivity is calculated at 11.4% of lifetime consumption in the case of FDC followed by 8.0% and 7.7% for NDC and DB respectively. These are somewhat large numbers, especially in the case of the DB system, where the main benefits arise from lower taxation. This large magnitude, however, may be explained by the fact that the policy intervention analyzed in our study is relatively stark. In fact, individuals are "forced" to raise the labor supply by approximately 15% relative to baseline. An increase in the retirement age is often treated as the simplest remedy to the unsustainability

of the pension systems – especially DB. Indeed, such reform turns out to be even more beneficial in the case of fully funded systems.

Most of the welfare gain comes from increased consumption. As depicted in Figure 6 (comparison for the final steady states), a shift towards larger consumption occurs in all systems, but only under DB the consumption post-reform strictly trumps the baseline. In fact, as expected, under actuarially fair systems agents prefer higher savings at young ages with higher retirement age. This effect comes from the fact that compulsory pension savings in the defined contribution systems have higher present value if they accrue for a longer period of time.

Figure 6: Consumption effects in the final steady states

(a) DB   (b) NDC   (c) FDC
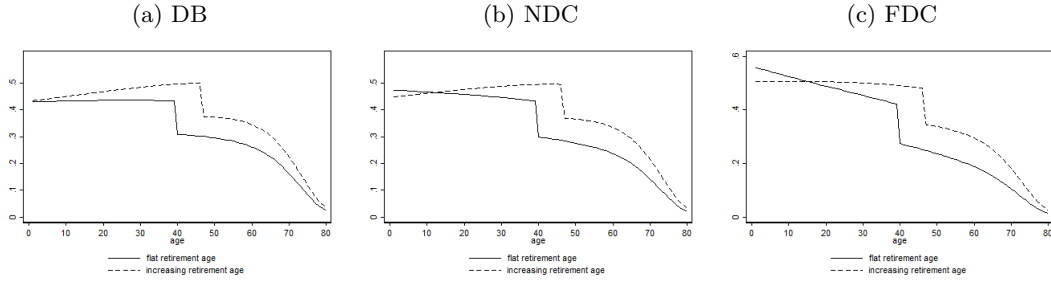
The long run effects on consumption are positive and they come from two sources: increasing the retirement age produces a step-wise consumption boost immediately in the period where the agents were not previously working. Second, there is a general increase in consumption of all the cohorts due to decreased government debt. The above welfare comparison seems to suggest that increased ("forced") labor supply allows the economy to find an equilibrium with lower taxation and higher output per effective unit of labor, let alone higher labor supply.

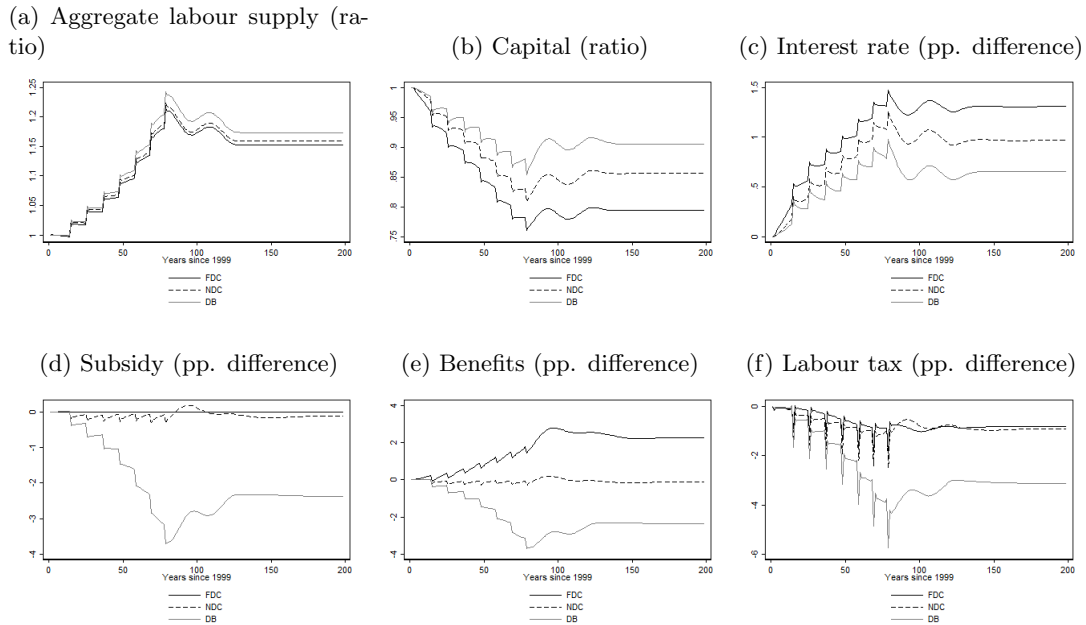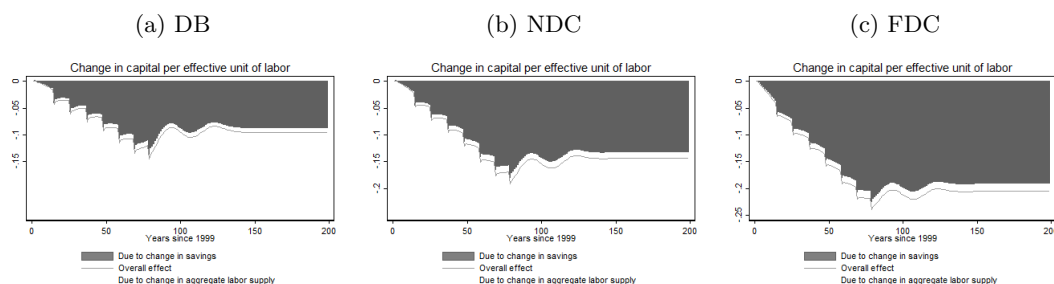Figure 7: Effects of retirement age increase (relative to the baseline)

(a) Aggregate labour supply (ratio)   (b) Capital (ratio)   (c) Interest rate (pp. difference)

(d) Subsidy (pp. difference)   (e) Benefits (pp. difference)   (f) Labour tax (pp. difference)

16

Figure 8: Capital effects of the reform - decomposition

(a) DB	(b) NDC	(c) FDC

Indeed, the change in the retirement age leads to a gradual increase in overall labor supply by slightly more than 15%, Figure 7. This change in labor supply is the highest under DB and the lowest under FDC. Please note, that with GHH preferences any reduction in labor supply during the lifetime reflects the changes in the relative price of labor only. Apart from the direct change related to the increase in retirement age, there is also a general equilibrium effect that relates to the change in labor taxation. The reduction in taxation in DB by 3 percentage points is the most pronounced across the pension schemes (under DC and FDC the long-run reduction in taxation is closer to 1 pp.).

With increasing labor supply, production in the economy becomes more labor-intensive, pushing the interest rate upwards. Capital per effective unit of labor falls by almost 10% under DB, slightly more under NDC and by over 20% under FDC. Majority of the adjustment happens via reduced savings (per capita and per effective unit of labor), Figure 8. With increasing marginal capital productivity, interest rates go up sharply, by over 1.5 pp. in FDC and considerable less under remaining pension schemes. While economic growth (per worker) slows down and interest rates go up, there is a large heterogeneity of effects on the annual expenditures on pension benefits, i.e. they increase in the capital-based FDC by over 40% in the long run and decrease slightly under NDC (based on economic growth), and under DB, where contributions are wage-based and with decreasing marginal productivity of labor, wages fall. Labor supply is now spread onto a higher number of periods. However, since under GHH preferences there is no wealth effect on life-cycle labor supply pattern, the per period adjustment is of minor nature. Both the effects on consumption and on labor supply are the most pronounced under the FDC pension scheme, where the boost in returns from accumulated savings allows the agents to consume more, while relatively lower price of labor is reflected by decreased labor supply over the life-cycle.

Table 3: Labor supply effects of the reform - decomposition

	Baseline overall LFP	Reform scenario			
		$j < 60$		$j \geq 60$	Total
		LFP	baseline=100	LFP	baseline=100
DB	57.9%	58.1%	100.2%	58.1%	117.3%
NDC	58.8%	58.2%	99.0%	58.2%	115.9%
FDC	59.8%	58.9%	98.4%	58.9%	115.2%

The above analysis shows that increasing the length of the working period is universally welfare enhancing, mainly because it allows to increase consumption in pre- and post-retirement period, relative to the baseline. Clearly, aging implies that with flat retirement age leisure grows, relatively speaking. Furthermore, with a larger working population, the

imbalances in the pension system are spread across more cohorts, which implies that gains from higher pensions are likely to outweight the costs of higher taxation due to pension system instability. Therefore, demographic assumptions may significantly affect the size of the effect that postponement of the retirement age has on welfare. To address this point in the next section we inquire how the effects change if we employ alternative demographic scenarios.

4.3 Robustness checks - demographics and productivity

Even with the milder pace of the demographic transition, raising the retirement age is still universally welfare enhancing. The consumption equivalent is roughly at the same level as in the the basic specification for the demographics (Table 5). The most visible difference is in the smoother transition paths that are due to the faster stabilization of population.

Table 4: Consumption equivalent as % of permanent consumption, flat productivity profile

Demographics	DB	NDC	FDC
Decreasing fertility	7.7%	8.0%	11.4%
Stable fertility	7.7%	8.3%	12.0%

In fact, there are large labor supply effects in the baseline simulation (see Figure 10 in the Appendix). Similar to welfare, there is almost no additional effect of the demographics on the way the *adjustment* to the change in the retirement age occurs, Figure 9. Since the alternative demographic scenario is more stylized, the adjustments are smoother. The only visible difference is in the size of a subsidy reduction due longer working period.

Finally, we inquire if and how much more could be gained by raising the retirement age if health and skills of the elderly continue to improve. So far, deteriorating health and outdated skills are considered the main causes of potentially lower productivity towards the end of the professional life. However, together with longevity, the number of years in good health increases as well, suggesting that this potential cause of productivity reduction will loose on importance in the coming future. Moreover, with raising tertiary enrollment, smaller and smaller part of the population will be at risk of having outdated skills. Versatility and adaptability which comes with more education is likely to affect the age-productivity patterns in the future. For Poland, despite massive restructuring and relatively high unemployment, the average age-productivity pattern over the past nearly two decades has already had a slightly increasing shape. To address this point, the final robustness check in this paper consist of simulating the policy change under age-productivity patterns derived from Deaton (1997) decomposition.

Indeed, there are additional welfare and macroeconomic effects if a fairly slowly increasing age-productivity patterns is assumed. As individual productivity increases with age, prolongation of the working age produces a sizable boost to aggregate productivity. The labor supply goes up by 20 percent under all pension systems. Increased (averaged) marginal productivity of labor (compared to the flat productivity) leads to a higher tax base and therefore it is possible to reduce the labor taxes by as much as 3pp. in the DB case and by less than 1pp. under the other pension systems, see Figure 12 in the Appendix. Productivity of capital goes up dramatically, which is reflected by a almost threefold long run increase of interest rates. The effects of disinvestment are also larger - output per effective unit of labor drops by almost 10% in the case of FDC and roughly half of that in the case of DB and NDC.

The extra years of working give agents the opportunity to not only enjoy increased consumption in the pre-retirement age but also to accumulate more and spend it over a

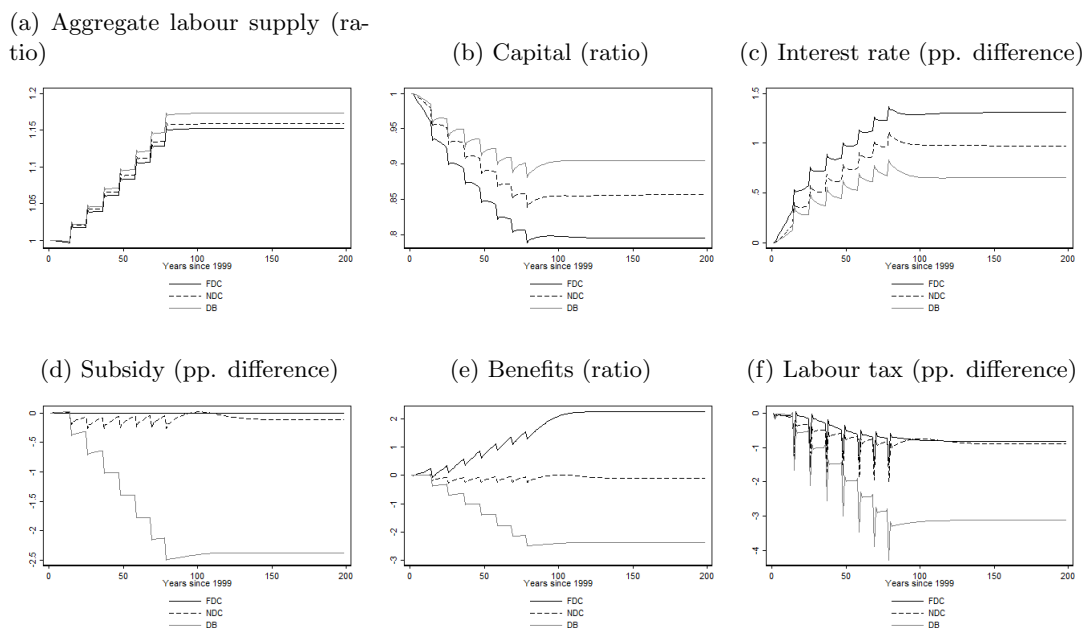Figure 9: Effects of retirement age increase - stable fertility rates

(a) Aggregate labour supply (ratio)

(b) Capital (ratio)

(c) Interest rate (pp. difference)

(d) Subsidy (pp. difference)

(e) Benefits (ratio)

(f) Labour tax (pp. difference)

Table 5: Consumption equivalent as % of permanent consumption, Deaton (1997) profile

Demographics	DB	NDC	FDC
Decreasing fertility	8.5%	9.5%	12.5%
Stable fertility	8.7%	10.0%	13.3%

shorter period of inactivity. Under DB the extra drop in taxes combined with increased consumption translate to a higher consumption equivalent than in the case of flat age-productivity pattern under FDC and NDC the welfare gains comes from higher interest rate in the former case and higher GDP growth in the latter.

5 Conclusions

There are two ways in which the demographic transition adversely affects the stability of the pension systems. Longevity implies longer periods in retirement, *ceteris paribus* whereas decreasing fertility reduces the size of the working population. Under defined benefit schemes, this structural change inevitably implies a considerable increase in pension system deficit or a downward adjustment in the replacement rate. Under defined contribution schemes, pension benefits decrease. Given the size of the demographic adjustment, the appropriate policy response has been a subject of a rather heated debate involving economists, policy makers and polititians. Keeping the *status quo* necessitates considerable fiscal adjustment, which amplifies the problem induced by the demographic transition even further. Amongst the analyzed solutions extending the minimum eligible pensionable age is one of the most frequently quoted.

Increasing the minimum eligible retirement age brings two potential benefits from the fiscal perspective. First, keeping workers longer in employment increases the contribution base *ceteris paribus*. Second, shortening the retirement period lowers overall pension expenditure and/or pension benefits, depending on the pension system. From a welfare perspective, these gains are accompanied by a cost in the form of substantially reduced

leisure. Therefore, increasing the retirement age is often regarded as an easy solution to population aging without the need to otherwise reform the pension systems, i.e. lowering the pensions either by adjusting the replacement rates in defined benefit systems or shifting towards schemes based on defined contributions.

The major questions we attempted to answer were the following: are pension system reforms and extending the working period interchangeable? Are there gains from increasing the minimum eligibility retirement age under defined contribution schemes as well? In principle, regardless of the pension scheme, increasing the retirement age improves the working time to retirement ratio and thus can improve the situations of agents via increased lifetime consumption.

We developed an overlapping generations model (calibrated closely to a transition economy, Poland), where we simulate the effects of a gradual increase in the retirement age across three pension schemes: pay-as-you-go defined benefit, pay-as-you-go defined contribution and a fully funded scheme. We find that gains from raising the retirement age can be universal and that they are *largest* in a fully-funded DC scheme. Raising the minimum pensionable age leads to a considerable improvement in the costs of running a DB scheme – the overall deficit in the pension system falls by more than 2.5pp in the long run.

However, operating a FDC pension system is even a better reason for such a policy change. We show that an increase in retirement age under FDC brings much higher welfare gains than under other pension systems. A decrease in capital to labor ratio improves the productivity of capital and greatly boosts the capital gains, which leads to a much higher rate of return on the FDC pensions. These translate to higher consumption and lower labor supply, both improving the welfare level. Under NDC the effects are slightly lower than under DB but still universally positive. Reduction in capital per effective unit of labor stems from two mechanisms: lowered private savings and increased aggregate labor supply. It is the former that quantitatively dominates.

We test the validity of our findings in a simulation setup, where demographics are more favorable, i.e. fertility rates do not drop. It seems that intensifying policies aimed at boosting births will not only be largely late but also much less effective than that of increasing the retirement age. The scope of population aging materializes relatively quickly in a majority of the advanced economies. Consequently, increasing the retirement age, while politically unpopular, should be implemented relatively quickly. Time inconsistency of economic policy may be an important factor preventing an optimal pace of implementation. This issue is a potential avenue for further research.

Finally, research points to the fact that longevity implies also longer life in good health, whereas steadily increasing human capital and skill biased technological change will inevitably lead to higher productivity at older ages. We contrast results of flat age-productivity profile with the calculations performed with a slightly increasing age-productivity pattern. Under such conditions postponing retirement brings even greater welfare gains (keeping fairly similar the differences between the pension systems). If additional working years occur under relatively high productivity, in addition to higher wages and higher contributions to the pension system, sizable aggregate productivity gains can be observed as well. In this context, promoting labor participation of 50+ population, continued education and training together with an appropriate health care system seem to be the policies guaranteeing greater benefits from raising the retirement age.

6 Appendix

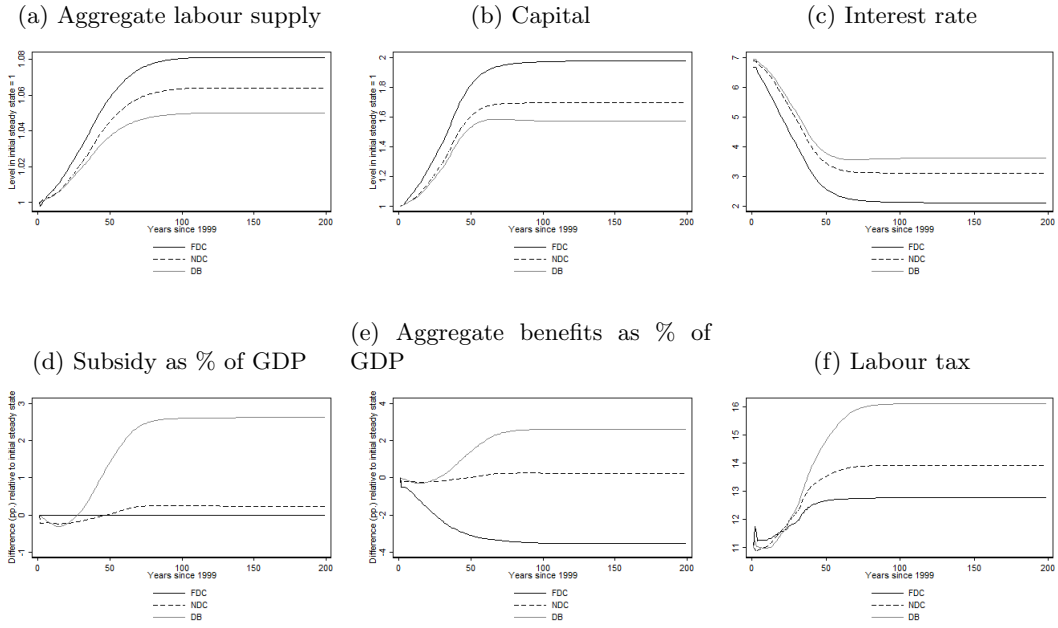Figure 10: Baseline with flat productivity and stable fertility rates

(a) Aggregate labour supply   (b) Capital   (c) Interest rate

(d) Subsidy as % of GDP   (e) Aggregate benefits as % of GDP   (f) Labour tax

Figure 11: Baseline with Deaton (1997) productivity and decreasing fertility rates

(a) Aggregate labour supply   (b) Capital   (c) Interest rate

(d) Subsidy as % of GDP   (e) Aggregate benefits as % of GDP   (f) Labour tax
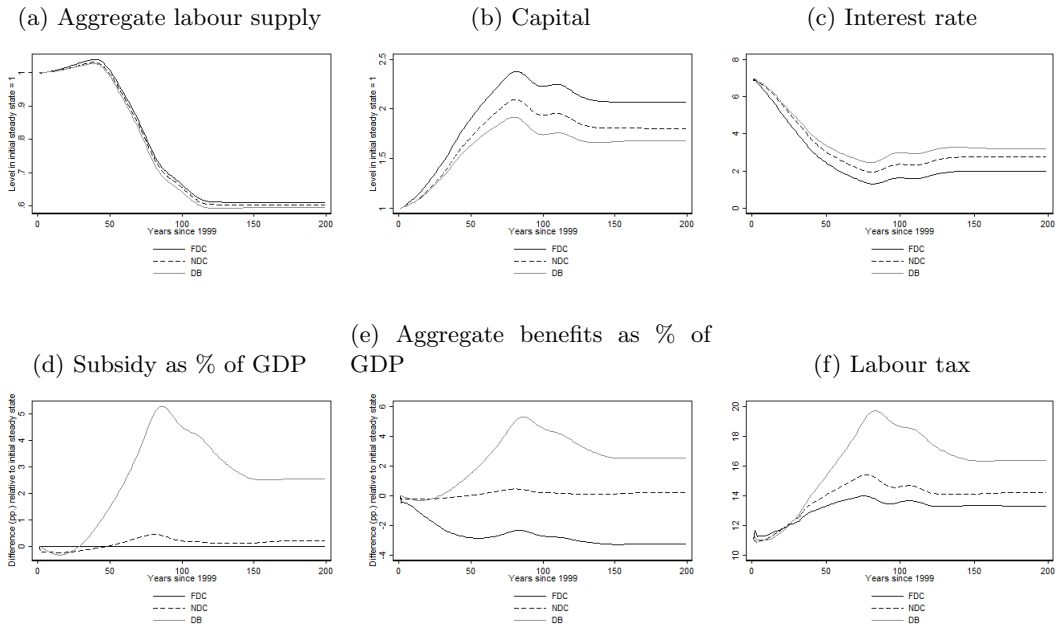
Figure 12: Effects of retirement age increase - Deaton productivity, decreasing fertility rates

(a) Aggregate labour supply (ratio)

(b) Capital (ratio)

(c) Interest rate (pp. difference)

(d) Subsidy (pp. difference)
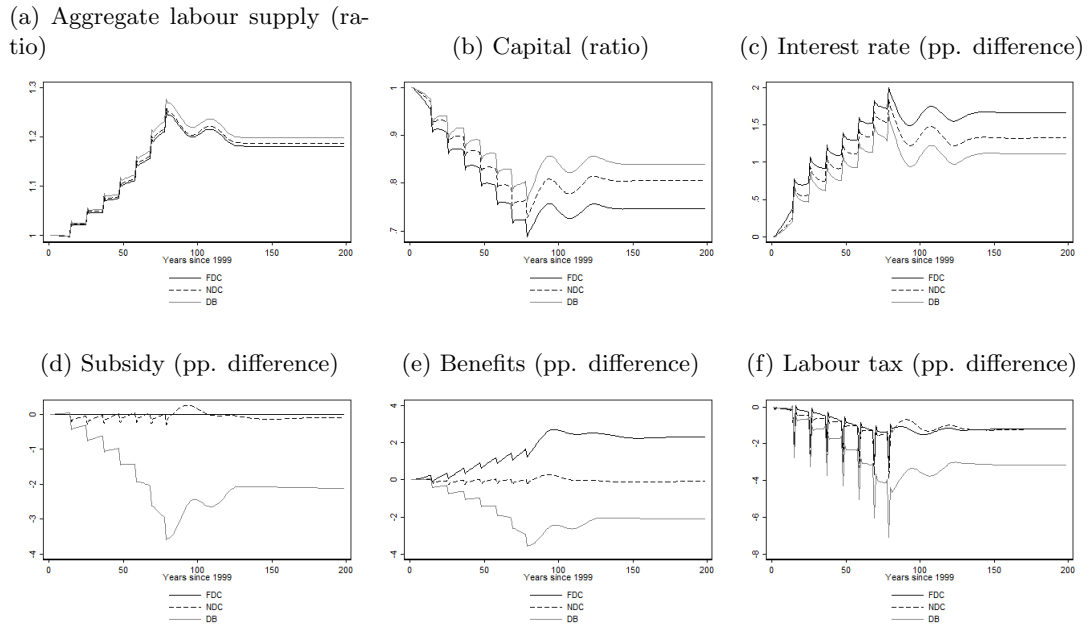
(e) Benefits (pp. difference)

(f) Labour tax (pp. difference)

Figure 13: Final steady state reform effects: consumption equivalent - Deaton (1997) productivity, decreasing fertility rates
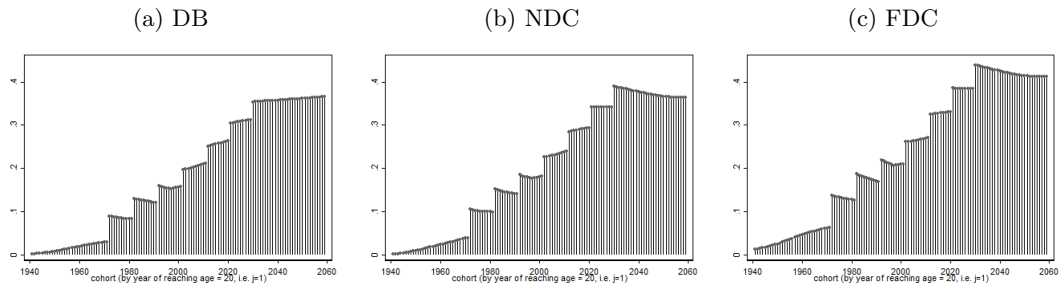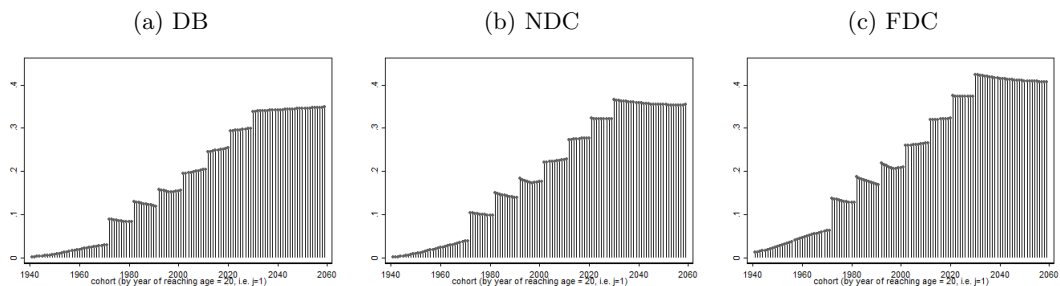
(a) DB

(b) NDC

(c) FDC

Figure 14: Final steady state reform effects: consumption equivalent - Deaton (1997) productivity, stable fertility rates

(a) DB

(b) NDC

(c) FDC

22

References

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

Ascari, G. and Rankin, N.: 2007, Perpetual youth and endogenous labor supply: A problem and a possible solution, *Journal of Macroeconomics* **29**(4), 708–723.

Auerbach, A. J., Kotlikoff, L. J., Hagemann, R. P. and Nicoletti, G.: 1989, The Economic Dynamics of an Ageing Population: The Case of Four OECD Countries, *OECD Economics Department Working Papers 62*, OECD Publishing.

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

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

Beetsma, R. M. and Bucciol, A.: 2011, Differentiating indexation in dutch pension funds, *De Economist* **159**(3), 323–360.

Berger, J., Keuschnigg, C., Keuschnigg, M., Miess, M., Strohner, L. and Winter-Ebmer, R.: 2009, Modelling of Labour Markets in the European Union Final Report Part II - Documentation of the Model, *mimeo*, Institute for Advanced Studies, University of St. Gallen.

Blanchard, O. J.: 1985, Debt, Deficits, and Finite Horizons, *Journal of Political Economy* **93**(2), 223–47.

Boersch-Supan, A.: 2013, Ageing, labour markets and well-being, *Empirica* pp. 1–11.

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

Boersch-Supan, A. and Ludwig, A.: 2013, Modeling the effects of structural reforms and reform backlashes: The cases of pension and labor market reforms, *Economic Modelling* **35**(C), 999–1007.

Boersch-Supan, A., Ludwig, A. and Winter, J.: 2006, Aging, Pension Reform, and Capital Flows: A Multi-Country Simulation Model, *Economica* **73**(292), 625–658.

Boersch-Supan, A. and Weiss, M.: 2011, Productivity and age: Evidence from work teams at the assembly line, *MEA discussion paper series 07148*, Mannheim Research Institute for the Economics of Aging (MEA), University of Mannheim.

Breyer, F.: 1989, On the intergenerational Pareto efficiency of pay-as-you-go financed pension systems, *Journal of Institutional and Theoretical Economics (JITE)/Zeitschrift für die gesamte Staatswissenschaft* **145**(4), 643–658.

De Nardi, M., Imrohoroglu, S. and Sargent, T. J.: 1999, Projected U.S. Demographics and Social Security, *Review of Economic Dynamics* **2**(3), 575–615.

Deaton, A.: 1997, *The analysis of household surveys: a microeconometric approach to development policy*, Johns Hopkins University Press.

Diamond, P. and Barr, N.: 2006, (UBS Pensions Series 041) The Economics of Pensions, *FMG Discussion Papers DP563*, Financial Markets Group.

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

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

Feldstein, M.: 1995, Would Privatizing Social Security Raise Economic Welfare?, *Working Paper Series 5281*, National Bureau of Economic Research.

Fenge, R. and Pestieau, P.: 2005, Social security and early retirement, *MIT Press Books* .

Fougere, M., Mercenier, J. and Merette, M.: 2007, A sectoral and occupational analysis of population ageing in Canada using a dynamic CGE overlapping generations model, *Economic Modelling* **24**(4), 690–711.

Fougere, M. and Merette, M.: 1999, Population ageing and economic growth in seven OECD countries, *Economic Modelling* **16**(3), 411–427.

Furlanetto, F. and Seneca, M.: 2014, Investment shocks and consumption, *European Economic Review* **66**, 111 – 126.

Galasso, V.: 2008, Postponing retirement: the political effect of aging, *Journal of Public Economics* **92**(10-11), 2157–2169.

Greenwood, J., Hercowitz, Z. and Huffman, G. W.: 1988, Investment, capacity utilization, and the real business cycle, *The American Economic Review* pp. 402–417.

Gruber, J. and Wise, D. A.: 2007, *Social Security Programs and Retirement around the World: Fiscal Implications of Reform*, number grub07-1 in *NBER Books*, National Bureau of Economic Research, Inc.

Guest, R.: 2007, Innovations in the macroeconomic modelling of population ageing, *Economic Modelling* **24**(1), 101–119.

Heer, B., Rohrbacher, S. and Scharrer, C.: 2014, Aging, the Great Moderation and Business-Cycle Volatility in a Life-Cycle Model, *CESifo Working Paper Series 4584*, CESifo Group Munich.

Heijdra, B. J. and Romp, W. E.: 2009, Retirement, pensions, and ageing, *Journal of Public Economics* **92**, 586–604.

Hviding, K. and Marette, M.: 1998, Macroeconomic effects of pension reforms in the context of ageing populations: Overlapping generations model simulations for seven OECD countries, *OECD Economics Department Working Paper 201*, OECD Publishing.

Jaimovich, N. and Rebelo, S.: 2009, Can News about the Future Drive the Business Cycle?, *American Economic Review* **99**(4), 1097–1118.

Jimeno, J. F., Rojas, J. A. and Puente, S.: 2008, Modelling the impact of aging on social security expenditures, *Economic Modelling* **25**(2), 201–224.

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

Kotlikoff, L. J. and Summers, L. H.: 1981, The Role of Intergenerational Transfers in Aggregate Capital Accumulation, *Journal of Political Economy* **89**(4), 706–32.

Kristensen, N.: 2012, Training and retirement, *Technical report*, Institute for the Study of Labor (IZA).

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

Ludwig, A.: 2005, Aging and Economic Growth: The Role of Factor Markets and of Fundamental Pension Reforms, *MEA discussion paper series 05094*, Mannheim Research Institute for the Economics of Aging (MEA), University of Mannheim.

Ludwig, A., Schelkle, T. and Vogel, E.: 2007, Demographic Change, Human Capital and Endogenous Growth, *MEA discussion paper series 07151*, Mannheim Research Institute for the Economics of Aging (MEA), University of Mannheim.

Miles, D.: 1999, Modelling the Impact of Demographic Change upon the Economy, *Economic Journal* **109**(452), 1–36.

Modigliani, F. and Ando, A. K.: 1957, Tests of the life cycle hypothesis of savings: comments and suggestions, *Bulletin of the Oxford University Institute of Economics & Statistics* **19**(2), 99–124.

Monacelli, T. and Perotti, R.: 2008, Fiscal Policy, Wealth Effects, and Markups, *NBER Working Papers 14584*, National Bureau of Economic Research, Inc.

Nakamura, E. and Steinsson, J.: 2014, Fiscal stimulus in a monetary union: Evidence from us regions, *American Economic Review* **104**(3), 753–92.

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

Picchio, M. and van Ours, J. C.: 2013, Retaining through training even for older workers, *Economics of Education Review* **32**(0), 29 – 48.

Schmitt-Grohe, S. and Uribe, M.: 2003, Closing small open economy models, *Journal of International Economics* **61**(1), 163–185.

Schmitt-Grohe, S. and Uribe, M.: 2012, What's news in business cycles, *Econometrica* **80**(6), 2733–2764.

Skirbekk, V.: 2004, Age and individual productivity: A literature survey, *Vienna yearbook of population research* pp. 133–153.

Stenberg, A. and Westerlund, O.: 2013, Education and retirement: does university education at mid-age extend working life?, *IZA Journal of European Labor Studies* **2**(1), 1–22.

van Sonsbeek, J.-M.: 2010, Micro simulations on the effects of ageing-related policy measures, *Economic Modelling* **27**(5), 968–979.

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