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The Interplay between trade unions and the social security system in
an aging economy

by

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THE INTERPLAY BETWEEN TRADE UNIONS AND THE SOCIAL SECURITY SYSTEM IN AN AGING ECONOMY ¹

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Abstract

This paper investigates how demographic change affects the financial sustainability of a pay-as-you-go social security system in an environment with collective bargaining on the labor market. Partial equilibrium analysis shows that the contribution rate or the benefit level decreases, if the old-age dependency ratio rises. The government balances the social security budget by aiming indirectly at a higher level of employment. In general equilibrium the opposite applies. The government increases the contribution rate (defined benefit) or the benefit level (defined contribution) due to additional effects of demographic change on capital accumulation and labor demand. In contrast to a perfect labor market scenario, the imposed financing burden from an aging society is overcompensated by favorable labor market effects on the social security budget.

JEL-Codes: H55, J11, J51

Keywords: demographic change, PAYG pension, social security, trade union, collective wage bargaining, unemployment

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1 Introduction

Increasing longevity and low fertility are phenomena which are highly relevant for the member states of the European Union (EU). Together both measures determine the old-age dependency ratio (AQ), which is defined as the proportion of the number of individuals above the age of 65 to the number of individuals between 15 - 65 years old. Figure 1 depicts projections from the European Commission (EC) for several countries of the EU. It shows that on average (EU 28) there will be a sharp rise of the AQ from around 32% in the year 2020 to 50% in 2040. Only in 2070 will the upward movement stop and peak at a value of around 55%. The severity of the development will differ between countries. While for Greece a peak of the AQ is projected only for the year 2050 at a ratio of 70%, the AQ in France is projected to be around 45% in the same year.

This demographic development has implications not only on how societies organize themselves but in particular also on capital and labor markets as well as the local social security systems. As [Schmähl \(1990\)](#) already notes, demographic developments do not only affect the social security system directly, e.g. by higher expenditures due to a higher number of benefit recipients, but also to a great extent indirectly via the effects of population aging on earnings and employment.

In Europe collective wage bargaining on the labor markets is of particular relevance. On one hand, the coverage level of collectively agreed wages is rather low in some EU member states such as Poland (17%), Hungary (23%) or the United Kingdom (26%). On the other hand, it is rather high e.g. in Italy (80%), Finland (89%) or France (98%) ([ETUI, 2019](#), p. 56). Though the different levels of coverage are widespread across countries, trade unions have a substantial impact on wage setting everywhere. Furthermore, social security systems with a public pay-as-you-go element are prevalent within the group of EU member states. While some countries rely on a defined benefit (DB) scheme, others prefer defined contributions (DC). Mixtures may also occur, like in Poland (see [EC, 2018](#)).

The aim of this paper is to reveal the implications of demographic change for the interplay of pay-as-you-go social security and labor markets, if wages are determined by collective wage bargaining. In the case of defined benefits (DB), allowing for interdependencies between the contribution rate and the collectively determined gross wage rate yields the surprising result that the contribution rate may shrink in response to higher longevity or lower fertility. This partial

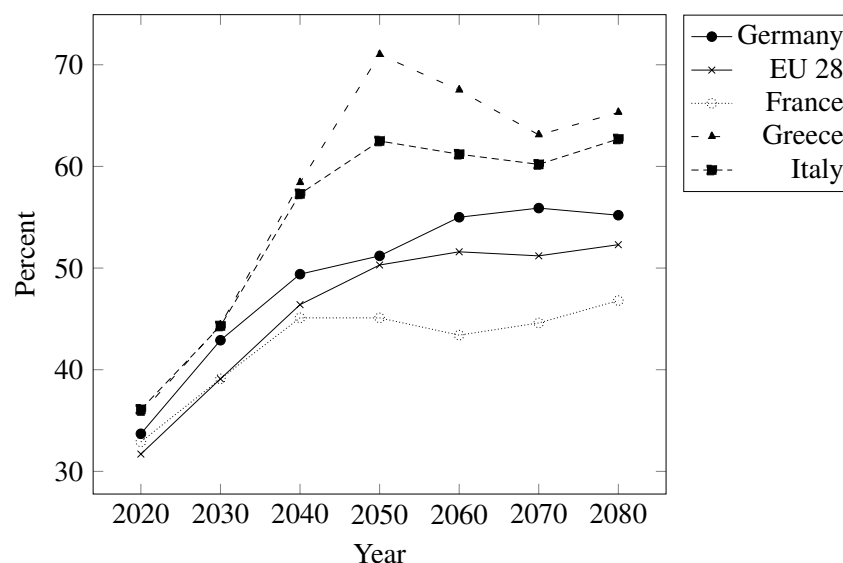


Fig. 1 Projected old-age dependency ratios, data from [Eurostat \(2019\)](#).

equilibrium result is obtained, because the tax base (payroll) is sensitive to the policy instrument of the government. In contrast to this *demographic effect*, a higher amount of capital supplied (e.g. due to higher savings of households) induces the government to increase the contribution rate. A numerical example shows that the latter *capital supply* effect on the contribution rate dominates the *demographic effect* in general equilibrium. With defined contributions (DC) a similar reasoning applies.

Furthermore, the comparison of DB with DC schemes shows that the transition path of the employment rate towards the new steady state is much more volatile with DB than with DC. This result can be explained by the partially disparate effects of the contribution rate and the benefit level on revenues and expenditures in the social security budget.

The basic structure of the model refers to the standard overlapping generations framework developed by Samuelson (1958) and Diamond (1965), which is extended by firm-level Nash bargaining over gross wages (see e.g. Booth, 1995). The aggregate gross wage, the aggregate employment level and the respective policy instrument of the social security system (DB or DC) determine the equilibrium on the labor market. It is assumed that the government balances the budget in each period. In doing so, the government is forced to consider the direct and indirect effects of the contribution rate or the benefit level on wages and employment. Furthermore, it is assumed that the economy is closed such that the rental rate of capital is responsive to adjustments of supply and demand. To derive analytical results, a Cobb-Douglas production technology and logarithmic utility functions are assumed.

The assumption of a balanced budget and the effect of the government's policy instrument on the gross wage level are key to understand the main results of the paper. The *demographic effect* directly increases expenditures, because a higher number of beneficiaries per capita is to be financed. In order to restore the balance of the budget, the government can increase revenues and it can decrease expenditures. In both cases, DB and DC, an increase of the contribution rate or the benefit level increases the wage level. Two indirect budget effects would emerge from this policy. Firstly, the tax base (revenues) is negatively affected. Secondly, the unemployment rate (expenditures) increases. Thus the government is induced to decrease the contribution rate or the benefit level in order to restore the balance of the budget. With DC, the two indirect effects are accompanied by a third direct expenditure effect. Decreasing the benefit level also decreases expenditures for a given number of beneficiaries. However, with DB, the third effect is a direct revenue effect. For a given tax base, a lower contribution rate decreases revenues, which deepens the initial imbalance of the budget. Whether the government then increases or decreases the contribution rate depends on the relative strength of the indirect and the direct effects. A necessary condition for the domination of the indirect effects is that the absolute value of the labor demand elasticity with respect to wages is higher than the wage bargaining mark-up on the tax-adjusted benefit level, which is assumed to hold throughout the paper.

In general equilibrium households supply a higher amount of capital due to demographic change (longevity driven aging) or capital disperses less strong per capita (fertility driven aging). Thus, in both cases firms are induced to demand more labor such that government's revenues increase (via the tax base) and expenditures decrease (via unemployment). As before, the government restores the balance of the budget. However, this indirect *capital supply effect* has the opposite effect on government's behavior than the direct *demographic effect*. This holds for DB as well as DC. The progression of the transition paths towards a new steady state then is mainly explained by the relative strength of both effects.

Relevant studies which consider the impact of demographic change on the sustainability of a pay-as-you-go pension system are Fanti and Gori (2008, 2010, 2012) and Cipriani (2014). Furthermore, Artige (2014), Tabata (2015) and Dedry et al. (2018) put a special comparative focus on the performance of defined-benefits and defined-contribution systems as well as on the

effect of demographic aging on economic growth.

In particular, [Tabata \(2015\)](#) identifies a so-called anti-dilution and a life-span effect of aging on capital accumulation. Population aging increases the capital intensity either due to less dispersion of capital among households or increased savings. Furthermore, [Tabata \(2015\)](#) finds that an increase of the old-age dependency ratio positively affects the social security tax rate such that individuals save less and capital accumulation decreases (the so-called tax burden effect). The total effect of population aging on economic growth then depends on the relative strength of these competing effects. However, the aforementioned studies consider perfect labor markets where no indirect labor market effects on the extensive margin emerge. To take account of these effects, this paper in turn considers imperfect labor markets with collective wage bargaining among trade unions and firms.

Only a few papers have considered the effect of demographic change and the social security system in a framework with imperfect labor markets already: e.g. [Keuschnigg and Keuschnigg \(2004\)](#), [de la Croix et al. \(2013\)](#), [Morimoto et al. \(2018\)](#). In particular, [de la Croix et al. \(2013\)](#) emphasize that labor market imperfections matter when evaluating pension systems and reforms under demographic pressure. If demographic change causes an expansion of capital supply, it may induce labor demand such that relatively more contributors to the social security system are available. However, the aforementioned papers consider equilibrium unemployment caused by search and matching. In contrast, this paper relies on collective wage bargaining. As in e.g. [Corneo and Marquardt \(2000\)](#) or [Ono \(2007\)](#), a link between the social security system and collective wage negotiations is implemented. This allows for the analysis of the direct and indirect effects of demographic change on savings, employment, the contribution rate and the benefit level of the social security system.

The paper is organized as follows. Chapter 2 develops the model. Chapter 3 defines the temporary and intertemporal equilibria of the economy. Chapter 4 presents a numerical example to consider general equilibrium effects. A short discussion of the model and the simulation results follows in chapter 5. Conclusions are drawn in chapter 6.

2 The model

The basic structure of the model refers to the standard OLG framework and is extended by collective wage bargaining on the labor market. Time is discrete and the economy is closed. A large number of identical households and identical firms exist in the economy. Households have perfect foresight, do not leave bequests and supply labor inelastically. Lifetime uncertainty is offset by a perfect insurance market. The social security system is characterized by proportional labor income taxes and a unitary social benefit which is transferred to the unemployed and the retirees.

2.1 Demography

In any discrete time period t , the population of the economy divides into two generations: the young and the old. All young individuals survive the first period of their lifetime, but on average only a fraction $0 < \pi_t \leq 1$ of the second period. The variable $Z_{y,t}$ denotes the number of young individuals and $Z_{o,t}$ the number of old individuals. Total population then amounts to

$$Z_t = Z_{y,t} + Z_{o,t} = Z_{y,t-1}(1 + x_t) + Z_{y,t-1}\pi_t \quad (1)$$

with $x_t > -1$ reflecting the young population's growth rate from period $t - 1$ to period t . The old-age dependency ratio is defined as the ratio of the number of the old to the young:

$$\frac{Z_{o,t}}{Z_{y,t}} = \frac{\pi_t}{1 + x_t} = A Q_t \quad (2)$$

Furthermore, the group of the young divides into the number of employed N_t and the number of unemployed U_t : $Z_{y,t} = N_t + U_t$.

2.2 Individuals

Young individuals are identical ex ante and supply one unit of labor each. An individual earns the gross wage w_t the share τ_t of which is taxed away, if employed with probability n_t . If unemployed with probability $u_t = 1 - n_t$, an individual receives the social benefit b_t . The disposable income is used to finance consumption $c_{y,t}$ and to build up savings s_t . In the second period of their lifetime, individuals retire and use their savings and their pension b_t to finance consumption $c_{o,t+1}$ during retirement. For simplicity social benefits are assumed to be identical for the unemployed and the retirees. The flow budget constraints of both lifetime periods are then given by

$$c_t = w_t(1 - \tau_t)n_t + b_t u_t - s_t \quad (3)$$

$$c_{t+1} = \frac{R_{t+1}}{\pi_{t+1}} s_t + b_{t+1} \quad (4)$$

The variable $R_{t+1} = 1 + r_{t+1}$ describes the return on income invested in firms' securities, with r_{t+1} representing the capital market price in period $t + 1$.

Lifetime uncertainty is offset by insurance companies which offer securities promising fixed payments in the retirement period. Following the interpretation of the survival probability π_t as reflecting the average individual length of the second lifetime period, the payments could be visualized as annuities that are paid at regular fractions of the respective time period. For the formal implementation of such an insurance it is assumed that the insurance companies are risk neutral and operate on competitive private annuity markets (see also [Yakita, 2001](#), [Cipriani, 2014](#)). The yield of the security then amounts to R_{t+1}/π_{t+1} .

A young individual optimizes life-time utility over both periods by choosing the optimal levels of consumption while young, $c_{y,t}$ and while old, $c_{o,t+1}$ as well as savings s_t . The time preference is denoted by β and utility $U(\cdot)$ is assumed to be additive, separable and logarithmic. The maximization problem is given by

$$\max_{c_t, c_{t+1}, s_t} u_{y,t}(c_t, c_{t+1}) = \ln(c_t) + \pi_{t+1} \beta \ln(c_{t+1}) \quad (5)$$

subject to the budget constraints (3) and (4). The following first-order condition results:

$$\frac{\partial u_{y,t}}{\partial s_t} = -\frac{1}{w_t(1 - \tau_t)n_t + b_t u_t - s_t} + \pi_{t+1} \beta \frac{\frac{1+r_{t+1}}{\pi_{t+1}}}{\frac{1+r_{t+1}}{\pi_{t+1}} s_t + b_{t+1}} \stackrel{!}{=} 0 \quad (6)$$

Solving for the optimal amount of savings s_t yields

$$s_t = \frac{\beta \pi_{t+1}}{1 + \beta \pi_{t+1}} \left[w_t(1 - \tau_t)n_t + (1 - n_t)b_t - \frac{b_{t+1}}{\beta(1 + r_{t+1})} \right] \quad (7)$$

Total savings in period t and thus total capital supply in period $t + 1$ are then given by

$$Z_t^y s_t = K_{t+1} \quad (8)$$

2.3 Labor market

The labor market in period t is characterized by a large number $i = 1, 2, \dots, I$ of respectively identical firms and trade unions. Each firm-union pair has symmetric bargaining power and negotiates the local gross wage w_t^i for a given number of union members $Z_{y,t}^i = Z_{y,t}/I$. It is assumed that each young individual is a member of a union in period t and that membership is equally distributed among all unions.

2.3.1 Firms

The production technology is of Cobb-Douglas type and yields the output $Y_t = F(K_t^i, N_t^i) = A(K_t^i)^\alpha (N_t^i)^{1-\alpha}$ by employing the amounts K_t^i of capital and N_t^i of labor. The parameter $A > 0$ denotes the total factor productivity and the parameter $0 < \alpha < 1$ the elasticity of output with respect to capital. Capital and labor are so-called q-complements, e.g. higher utilization of capital in production increases the demand for labor due to higher marginal productivity: $F_{K_t^i N_t^i} > 0$ (see also [Seidman, 1989](#)). Firms issue securities to gather the required capital for production. For one unit of capital investment, firms pay an interest of r_t on the capital market. Furthermore, capital depreciates completely at the end of each period. The representative firm's objective function then is to maximize profit P_t^i by choosing the amounts K_t^i and N_t^i :

$$\max_{K_t^i, N_t^i} P_t^i = A(K_t^i)^\alpha (N_t^i)^{1-\alpha} - (1 + r_t)K_t^i - w_t^i N_t^i \quad (9)$$

The first-order conditions for a profit maximum in firm i are

$$\frac{\partial P_t^i}{\partial K_t^i} = \alpha A \left(\frac{N_t^i}{K_t^i} \right)^{1-\alpha} \stackrel{!}{=} 1 + r_t \quad (10)$$

$$\frac{\partial P_t^i}{\partial N_t^i} = (1 - \alpha) A \left(\frac{K_t^i}{N_t^i} \right)^\alpha \stackrel{!}{=} w_t^i \quad (11)$$

Condition (11) implies profit maximizing labor demand $N_t^i(w_t^i)$ and allows for the derivation of the local employment rate at the firm-union pair i :

$$n_t^i = \left(\frac{A(1 - \alpha)}{w_t^i} \right)^{\frac{1}{\alpha}} k_t^i \quad (12)$$

with $n_t^i = N_t^i/Z_{y,t}^i$ and $k_t^i = K_t^i/Z_{y,t}^i$.

2.3.2 Wage setting

The local trade union's objective in the Nash bargain is given by the sum of utilities $SU_{y,t}^i$ of its members. Employed members at firm i earn the gross wage w_t^i the share τ_t of which is taxed away, and unemployed members of trade union i receive the social benefit b_t . With logarithmic utility, the following objective function results

$$SU_{y,t}^i = N_t^i \ln(w_t^i(1 - \tau_t)) + (Z_{y,t}^i - N_t^i) \ln(b_t) \quad (13)$$

Several assumptions are implied in equation (13). First, old individuals are excluded from membership and unions care only about those young individuals who are members of the respective trade union (compare e.g. [Lingens, 2012](#), ch. 2).¹ Second, no intertemporal trade-off occurs for

¹Alternatively and without loss of generality, it can be assumed that due to capital investment the old own the firms, and wage negotiations in any period t take place between the old and the young.

any trade union, i.e. the effect of wage setting on savings in period t is not taken into account. Third, the macroeconomic variables τ_t and b_t as well as membership $Z_{y,t}^i$ are taken as given from a single union's perspective. This implies that the outside option of a local trade union is given by $\overline{SU}_t^i = Z_{y,t}^i \ln(b_t)$.

The objective function of a firm is its profit P_t^i . It is assumed that the stock of capital is installed in advance of wage setting, which means that the outside option of the firm is $\overline{P}_t^i = -(1 + r_t)K_t^i$ (see also [Devereux and Lockwood, 1991](#)).

The symmetric Nash bargaining problem at the firm-union pair i is subject to implicit optimal local labor demand (11) and reads as:

$$\max_{w_t^i} V_t^i = (A(K_t^i)^\alpha (N_t^i)^{1-\alpha} - w_t^i N_t^i) (N_t^i [\ln(w_t^i(1 - \tau_t)) - \ln(b_t)]) \quad (14)$$

with the first-order condition

$$\begin{aligned} \frac{dV_t^i}{dw_t^i} = & \left(A(K_t^i)^\alpha (1 - \alpha) (N_t^i)^{-\alpha} \frac{\partial N_t^i}{\partial w_t^i} - N_t^i - w_t^i \frac{\partial N_t^i}{\partial w_t^i} \right) (N_t^i [\ln(w_t^i(1 - \tau_t)) - \ln(b_t)]) \\ & + (A(K_t^i)^\alpha (N_t^i)^{1-\alpha} - w_t^i N_t^i) \left(\frac{\partial N_t^i}{\partial w_t^i} [\ln(w_t^i(1 - \tau_t)) - \ln(b_t)] + N_t^i \frac{1}{w_t^i} \right) \stackrel{!}{=} 0 \end{aligned} \quad (15)$$

The following local wage setting curve results:

$$w_t^i = \frac{b_t}{1 - \tau_t} \mu \quad (16)$$

where $\mu = e^{\frac{\alpha}{2-\alpha}}$ is a mark-up on the alternative income b_t , with e as Euler's number and tax-adjusted by $1/(1 - \tau_t)$. The wage level at the firm-union pair i depends on aggregate variables and the output elasticity of capital only.² Therefore, the local wage level (16) is equal among all firm-union pairs such that $w_t^1 = w_t^2 = \dots = w_t^I = w_t$ holds. Note that the local as well as the aggregate wage level depend positively on the contribution rate and the benefit level.

2.4 Social security budget

Expenditures for social security are financed via a pay-as-you-go transfer system, implying inter- and intra-generational redistribution. With a defined benefit scheme the contribution rate τ_t balances the budget while the benefit level b_t is fixed. Vice versa the same applies with defined contributions. In both cases the budget of the government balances tax revenues with total expenditures: $w_t \sum_{i=1}^I N_t^i \tau_t = b_t (U_t + Z_{o,t})$.

3 Equilibria

This section defines and analyzes the inter-temporal and the temporary equilibria of the model. A special focus is given to the analysis of the temporary labor market equilibrium. The theoretical mechanisms revealed in this section are decisive for the explanation of the general equilibrium results obtained in the simulations.

²Note that the level of membership $Z_{y,t}^i$ does not affect the local wage level.

3.1 Temporary equilibrium

Labor market Due to the symmetry assumption, $w_t^i = w_t$, $n_t^i = n_t$ and $k_t^i = k_t$ hold. Then, the following three equations define the temporary equilibrium on the labor market in period t :

$$\text{Aggregate wage level:} \quad w_t = \frac{b_t}{1 - \tau_t} \mu \quad (17)$$

$$\text{Aggregate employment rate:} \quad n_t = \left(\frac{A(1 - \alpha)}{w_t} \right)^{\frac{1}{\alpha}} k_t \quad (18)$$

$$\text{Social security budget:} \quad w_t n_t \tau_t = b_t (1 - n_t + A Q_t) \quad (19)$$

Defined benefits: The system of non-linear equations (17) - (19) can be solved implicitly for the contribution rate τ_t :

$$F \equiv w_t(\tau_t) n_t(w_t(\tau_t), k_t) \tau_t - b_t (1 - n_t(w_t(\tau_t), k_t) + A Q_t) = 0 \quad (20)$$

For plausible parameter values, a unique value $\tau_t(k_t)$ solves equation (20).³ Thus, it defines the temporary labor market equilibrium in dependency of the capital per capita ratio k_t and yields the equilibrium values $w_t(\tau_t(k_t))$ and $n_t(k_t, w_t(\tau_t(k_t)))$.

In each period t the government balances the social security budget (19) by adjusting the contribution rate τ_t . Thereby it takes into account how aggregate wage setting and aggregate labor demand respond to changes of the contribution rate. The government's response to an exogenous change of the old-age dependency ratio $A Q_t$ is obtained by applying the implicit function theorem on (20) with respect to τ_t and $A Q_t$: $d\tau_t/dA Q_t = -F_{A Q_t}/F_{\tau_t}$. Throughout the paper this implicit derivative is called the *demographic effect* on the contribution rate. The corresponding partial derivatives are given by

$$F_{A Q_t} = -b_t < 0 \quad (21)$$

$$F_{\tau_t} = \underbrace{w_t n_t}_{\substack{\text{direct revenue effect} \\ > 0}} + \underbrace{\left[\left(1 + \frac{dn_t}{dw_t} \frac{w_t}{n_t} \right) n_t \tau_t + \frac{dn_t}{dw_t} b_t \right]}_{\substack{\text{indirect revenue effects} < 0 \\ \text{indirect expenditure effect} < 0}} \frac{dw_t}{d\tau_t} \begin{matrix} \leq 0 \\ \geq 0 \end{matrix} \quad (22)$$

Equation (21) shows that a rising old-age dependency ratio $A Q_t$ increases the financial burden in the social security budget by the amount of additional benefits to be financed. Equation (22) in turn shows how an adjustment of the contribution rate affects revenues and expenditures of a balanced budget. The direct effect on revenues is of positive sign, because for a given tax base, e.g. a higher proportional contribution rate increases the revenue. The indirect revenue effects are of negative sign in total, because with Cobb-Douglas production technology the impact of employment level adjustments on the tax base is stronger than the wage effects: $\frac{dn_t}{dw_t} \frac{w_t}{n_t} = -1/\alpha < -1$. Furthermore, the indirect expenditure effect is of negative sign which is due to the change in the number of beneficiaries in response to an adjustment of the contribution rate. Thus, e.g. a higher contribution rate indirectly increases expenditures and indirectly decreases revenues.

Summarizing, a rising old-age dependency ratio increases the contribution rate, $d\tau_t/dA Q_t > 0$, if the direct revenue effect outweighs the indirect effects, and vice versa. In the special case that the indirect effects countervail the direct effect, the implicit derivative $d\tau_t/dA Q_t$ is not defined, because the balance of the budget is not affected by a change of the contribution rate.

³Assuming $0 < \alpha \leq 0.63$ guarantees a unique solution. See Appendix A, Lemma 1.

Now, consider the effect of the capital stock on the contribution rate: $d\tau_t/dk_t = -F_{k_t}/F_{\tau_t}$. Throughout the paper this implicit derivative is called the *capital supply effect* on the contribution rate. The denominator is given by equation (22) while the numerator is given by

$$F_{k_t} = (w_t \tau_t + b_t) \frac{n_t}{k_t} > 0 \quad (23)$$

According to the partial derivative (23), an increase of the capital stock per capita increases the tax revenues, because the level of employment increases, and vice versa. For the very same reason expenditures simultaneously decrease as less unemployed have to be granted a social benefit. In total, a rising capital intensity then decreases the contribution rate, $d\tau_t/dk_t < 0$, if the direct revenue effect outweighs the indirect effects in equation (22), and vice versa.

Defined contributions: The system of non-linear equations (17) - (19) can be solved implicitly for the benefit level b_t :

$$F \equiv w_t(b_t)n_t(w_t(b_t), k_t)\tau_t - b_t(1 - n_t(w_t(b_t), k_t) + AQ_t) = 0 \quad (24)$$

The *demographic effect* on the benefit level, $db_t/dAQ_t = -F_{AQ_t}/F_{b_t}$ is given by the following partial derivatives:

$$F_{AQ_t} = -b_t < 0 \quad (25)$$

$$F_{b_t} = \underbrace{-(1 - n_t + AQ_t)}_{\text{direct expenditure effect} < 0} + \left[\underbrace{\left(1 + \frac{dn_t}{dw_t} \frac{w_t}{n_t}\right) n_t \tau_t}_{\text{indirect revenue effect} < 0} + \underbrace{\frac{dn_t}{dw_t} b_t}_{\text{indirect expenditure effect} < 0} \right] \frac{dw_t}{db_t} < 0 \quad (26)$$

In analogy to the DB case, equation (25) shows that expenditures increase due to a rising old-age dependency ratio AQ_t . However, the sign of the denominator (26) is unambiguously negative. A higher benefit level increases expenditures directly while the indirect effects decrease revenues and also increase expenditures. Thus, with DC a rising old-age dependency ratio induces the government to decrease the benefit level for a given value of the capital intensity: $db_t/dAQ_t < 0$.

The *capital supply effect* on the benefit level then, $db_t/dk_t = -F_{k_t}/F_{b_t} > 0$ is of positive sign as its numerator is given by (23) and its denominator by (26). A higher level of capital per capita increases the benefit level.

Capital market Given the equilibrium on the labor market, the temporary equilibrium on the capital market in period t is defined by the market price for capital, which equalizes capital supply $k_t = s_{t-1}/(1 + x_t)$ from the old and capital demand of the firms:

$$1 + r_t = \alpha A \left(\frac{n_t(k_t)}{k_t} \right)^{1-\alpha} \quad (27)$$

Goods market Given the temporary equilibria on the labor and the capital market, the equilibrium on the goods market in period t requires that production Y_t equals consumption of the young and the old in period t plus the young's savings:

$$Y_t = Z_{t-1} \pi_t c_t^o + Z_t^y c_t^y + Z_t^y s_t \quad (28)$$

Rewriting (28) in terms of per young capita yields

$$F_t(k_t, n_t) = (1 + r_t)k_t + w_t n_t \quad (29)$$

which holds true by Euler's theorem.

Temporary equilibrium Given the variable s_{t-1} from period $t - 1$ and the expected variables b_{t+1} and r_{t+1} , the temporary equilibrium of period t is defined by

1. the wage level w_t and the return on capital R_t ,
2. the aggregate variables N_t, n_t, K_t, k_t, Y_t ,
3. the social security variables τ_t, b_t
4. and the individual variables c_t, c_{t+1}, s_t

that satisfy the four optimality conditions (6), (10), (11), (15), and the three equilibrium conditions (20), (27) and (29).⁴

3.2 Intertemporal equilibrium

Any two successive periods t and $t + 1$ are linked via the law of motion of the capital stock, equation (8). Taking account of the optimality and equilibrium conditions yields:

$$\begin{aligned} \text{DB: } k_{t+1} &= \frac{1}{1+x_{t+1}} \frac{\pi_{t+1}\beta}{1+\pi_{t+1}\beta} \left[w_t(k_t)(1-\tau_t(k_t))n_t(k_t) + (1-n_t(k_t))b_t - \frac{b_{t+1}}{\beta(1+r_{t+1}(k_{t+1}))} \right] \\ \text{DC: } k_{t+1} &= \frac{1}{1+x_{t+1}} \frac{\pi_{t+1}\beta}{1+\pi_{t+1}\beta} \left[w_t(k_t)(1-\tau_t)n_t(k_t) + (1-n_t(k_t))b_t(k_t) - \frac{b_{t+1}(k_{t+1})}{\beta(1+r_{t+1}(k_{t+1}))} \right] \end{aligned}$$

An intertemporal equilibrium with perfect foresight then is a sequence of temporary equilibria that satisfies the accumulation rule of capital and the formation of expectations with respect to r_{t+1} , and b_{t+1} in the case of DC.

4 Numerical example

The simulation shows how demographic change affects the intertemporal equilibrium of the model presented in section 2. In particular it considers how simultaneous adjustments of the contribution rate or the benefit level and the capital stock affect the labor market conditions and the financing of social security.

4.1 Calibration

Table 1 lists the assumptions for the exogenous variables. They do not replicate the conditions of a certain country. The values of the total factor productivity (TFP), A , the benefit level b (with DB) and the contribution τ (with DC) guarantee that the endogenous level of employment is below unity. Table 2 presents the two considered demographic scenarios. Prior to the demographic shift, the economy is in a steady state. In period $t = 0$ the economy experiences either of the following demographic shocks. Scenario a) describes the case of rising longevity while fertility stays at a constant level. In scenario b) the same applies vice versa. Both scenarios imply a rise of the old-age dependency ratio from $AQ_{-1} = 0.4$ to $AQ_0 = 0.6$.

⁴Definition and analysis of temporary and intertemporal equilibria for a basic two-period OLG model can be found in [de la Croix and Michel \(2002\)](#).

Variable	Value	Variable	Value
Output elasticity of capital:	$\alpha = 1/3$	TFP:	$A = 20$
Subjective discount rate:	$\beta = 1$		
Contribution rate (DC):	$\tau = 0.4$	Social benefit (DB):	$b = 9.71$

Table 1 Exogenous variables.

Scenarios	Longevity	Population growth rate	Implied AQ
Initial steady state	$\pi_{-1} = 0.3$	$x_{-1} = -0.25$	$AQ_{-1} = 0.4$
a) Longevity	$\pi_0 = 0.45$	$x_0 = -0.25$	$AQ_0 = 0.6$
b) Fertility	$\pi_0 = 0.3$	$x_0 = -0.5$	$AQ_0 = 0.6$

Table 2 Demographic scenarios.

4.2 Results

This section explains the simulation results with respect to the most relevant findings. The transition paths of savings, employment and the government's policy instruments are considered and compared to each other. With defined benefits, the periods $t = -1$ to $t = 1$ are characterized by non-trivial adjustment dynamics. From period $t = 1$ onward, the economy converges with diminutive damped oscillations to its new steady state. The case of defined contributions is mostly characterized by gradual adjustment paths toward the new steady state.

4.2.1 Savings

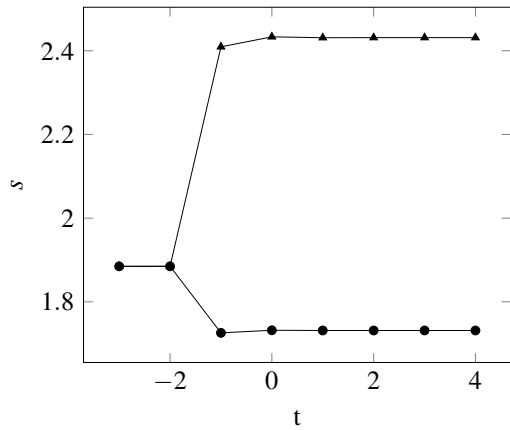
Firstly, consider scenario a) with a rise of longevity in period $t = 0$. For DB, figure 2(a) shows that per capita savings increase in period $t = -1$. The young anticipate the higher average length of the second lifetime period, which increases the weight of old-age consumption in the lifetime utility function. Due to this life-span effect on savings in period $t = -1$,⁵ the amount of productive capital in period $t = 0$ increases, too (see Appendix B). Savings increase once more in period $t = 0$ though the interest rate decreases from period $t = 0$ to period $t = 1$. This behavior of households is explained by more favorable labor market conditions and a rise in expected net income in period $t = 0$. For DC, figure 2(b) shows a very similar development. Differences in the progression of the transition path can be explained by the different mechanical impacts of the contribution rate and the benefit level on the budget.

The transition paths obtained in scenario b) differ from those obtained with longevity driven aging. With fertility driven aging, old-age consumption does not get a higher weight in the lifetime utility function. Instead the capital per young worker increases directly in period $t = 0$ due to the anti-dilution effect.⁵ However, only the negative effect of a lower interest rate remains and the young in period $t = -1$ decrease savings. In analogy to longevity driven aging, savings increase in period $t = 0$ due to more favorable labor market prospects.

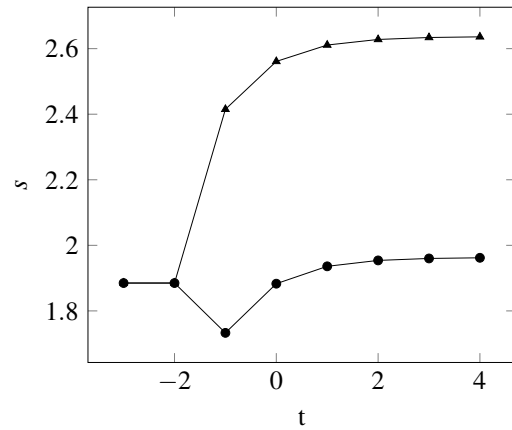
4.2.2 Employment and policy instruments

Figures 2(c) and 2(e) show the transition of the employment rate and the contribution rate in the case of DB. For setting of the contribution rate in period $t = 0$, two developments are decisive. First, the old-age dependency ratio increases. Second, more capital is used in production, which induces additional labor demand. For the chosen calibration of the model ($0 < \alpha \leq 0.63$), the indirect revenue and expenditure effects in equation (22) outweigh the direct revenue effect.

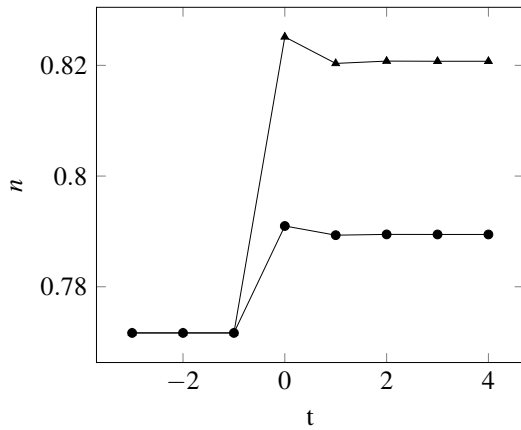
⁵See also Tabata, 2015 and Dedry et al., 2018 who carve out the life-span as well as the anti-dilution effect.



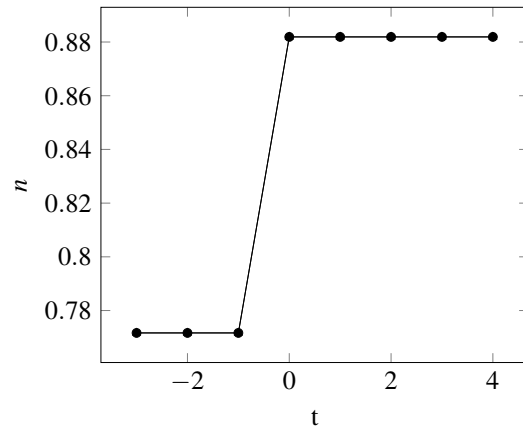
(a) DB. Savings.



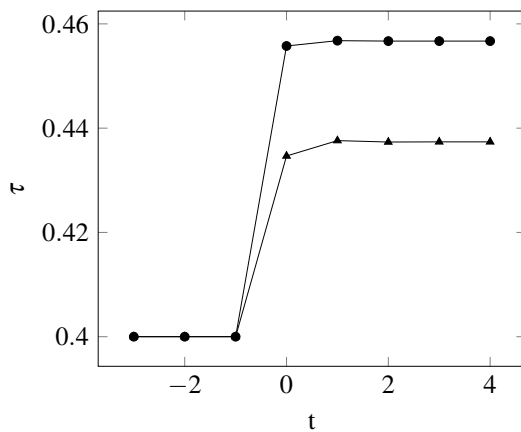
(b) DC. Savings.



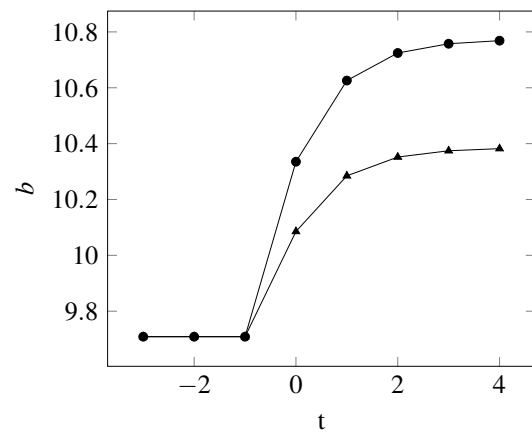
(c) DB. Employment.



(d) DC. Employment.



(e) DB. Contribution rate.



(f) DC. Social benefit.

—▲— Longevity —●— Fertility

Fig. 2 Simulation results DB and DC. Demographic shock in period $t = 0$.

Thus, the demographic effect induces the government to set a lower contribution rate while the capital supply effect does the opposite (see equations (21) and (23)). If both effects were equally strong, employment would increase while the level of the contribution rate would not change. However, figures 2(c) and 2(e) show that both, the employment rate as well as the contribution rate, take higher levels in period $t = 0$. This means that the capital supply effect does not only cover the inflicted financial burden from demographic change, but itself leads to an imbalance of the social security budget: *ceteris paribus*, revenues are higher than expenditures. To balance the budget again, the government is induced to partially reverse the favorable effect of higher capital supply on revenues and expenditures. This behavior is driven by the fact that the government is only concerned with a balanced budget, and does not redistribute the windfall profits. Therefore, the contribution rate increases such that the trade unions negotiate a higher wage level in period $t = 0$ (see Appendix B), and part of the induced additional labor demand is crowded out.

Due to the higher probability of being employed as well as the higher wage level, savings in period $t = 0$ increase again such that the amount of productive capital in period $t = 1$ increases, too. As before, this implies a capital supply effect on the contribution rate via additional labor demand. *Ceteris paribus*, revenues increase while expenditures decrease. To balance the budget, the government then aims at a higher contribution rate such that wages rise and employment decreases. However, there is no demographic effect which increases expenditures. Therefore, the imbalance of the budget in period $t = 1$ is relatively more severe than in period $t = 0$. The negative effect of the contribution rate on the level of employment overcompensates the positive effect of a higher amount of productive capital per capita. Thus, equilibrium employment in period $t = 1$ does not increase but decreases.

For the case of DC figures 2(d) and 2(f) show the transition paths of the employment rate and the level of the social benefit. In contrast to DB, employment immediately adjusts to the new steady state value. This phenomenon is explained by the different impacts of the contribution rate (DB) and the social benefit (DC) on the balance of the budget. In both cases, period $t = 1$ is characterized by a higher value of the capital intensity, which increases revenues and decreases expenditures via induced labor demand. With DC this capital supply effect can be exactly offset by an appropriate increase of the benefit level. This is the case, because on the aggregate level, capital supply or benefit level adjustments only affect the employment rate.⁶ With DB an adjustment of the contribution rate does not only affect labor demand but also the tax base. The effect on the tax base cushions the intended effect on labor demand respectively employment (see the direct and indirect effects in the partial derivative (22)). Thus any effort to offset the induced imbalance of the budget via an adjustment of the contribution rate (DB) must be relatively stronger than a similar attempt via an adjustment of the benefit level (DC). Therefore the policy of the government with DB is accompanied by a drop in employment in period $t = 1$.

5 Discussion

The results of the paper are derived in a model that makes some simplifying assumptions on a couple of real world conditions, e.g. with respect to wage setting and social security systems. An important assumption made is that the aggregate wage level depends directly on the conditions of the social security system. In the paper the negotiated gross wage depends on the benefit level as well as the contribution rate. Other specifications, which for example tie the

⁶Substituting the aggregate wage level (17) into the social security budget (24) yields: $F \equiv \mu n_t(b_t, k_t)\tau_t / (1 - \tau_t) - (1 - n_t(b_t, k_t) + AQ_t) = 0$. Adjustments of k_t and b_t affect only aggregate labor demand such that the capital supply effect is countervailed by an appropriate adjustment of the benefit level.

benefit level to the net wage, could imply a less dynamic or no interaction between the labor market and the social security system. Furthermore, the social security system considers only one tier of real world social security systems. Funded or earnings related components are not considered in the paper.

Several well-known effects of demographic change on capital accumulation do also apply to the developed model with collective wage bargaining on the labor market (e.g. the anti-dilution and the life-span effects). Additional novel effects revealed in the paper concern the interplay of collective wage bargaining and the social security system. Prescinding from governmental welfare objectives, the simple assumption of a balanced budget shows that demographic change does not necessarily imply lower benefit levels or higher contribution rates. It also reveals that different financing schemes imply different dynamics of the employment rate. These results, however, are obtained, because the output elasticity of capital is assumed to take values in a certain range. Furthermore, it was shown that a necessary condition for a unique labor market equilibrium requires the absolute value of the labor demand elasticity to be higher than the bargaining wage-mark up.

6 Conclusion

This paper investigated how demographic change affects the financial sustainability of a pay-as-you-go social security system in an environment with collective bargaining on the labor market. Analytically, the following could be shown.

First, in partial equilibrium a higher old-age dependency ratio decreases the proportional contribution rate (defined benefits) or the benefit level (defined contributions). The qualitative effect is identical, because both policies decrease the wage rate and increase employment. However, due to demographic change the social security expenditures increase. To offset the resulting imbalance, the government can increase tax revenues and simultaneously decrease social expenditure by adjusting the contribution rate or the benefit level downward. This behavior is reasonable, because it is assumed that the negative indirect wage and employment effects on revenues and expenditures are stronger than the positive direct revenue effect of a contribution rate adjustment.

Second, in a partial equilibrium a higher level of the capital intensity leads to a higher contribution rate or a higher level of the social benefit. Due to increased capital supply labor demand increases such that more contributors to the social security system are available. Simultaneously expenditures decrease due to a smaller number of beneficiaries. *Ceteris paribus*, the budget is unbalanced, because revenues increase and expenditures decrease. In this situation, a lower contribution rate or a lower benefit level would increase revenues and decrease expenditure even further. Therefore, the government adjusts the contribution rate or the benefit level upward, which attenuates the effect of additional labor demand and therefore balances the budget. As before, this result is obtained, because the negative indirect effects of a contribution rate adjustment are stronger than the positive direct effect.

General equilibrium effects of demographic change were investigated by calculating steady state values and transition paths for a calibrated economy. In contrast to the temporary equilibrium effect, it can be shown that the contribution rate as well as the benefit level ultimately increase, if the old-age dependency ratio rises. The reason for that rise is much different in comparison to a perfect labor market scenario where the wage and employment levels may be unaffected by adjustments of the government's instruments. With a perfect labor market individual contributions had to increase or received benefits to decrease in order to cover the additional financing burden. In the setup of this paper with an imperfect labor market due to collective bargaining, an adjustment of the policy instruments causes indirect effects on the labor market

which in turn affect revenues and expenditures of the government. The two aforementioned partial equilibrium effects apply simultaneously in the period of the demographic shock. The net effect of both ultimately increases the contribution rate or the benefit level. Furthermore, due to the continued upward adjustment of the capital stock, the capital supply effect is at work in each successive period until the new steady state is reached. In the long-run, the economy then is characterized by a higher contribution rate or benefit level, but also by a higher employment rate and a higher gross wage level. This holds for defined benefit as well as defined contribution rate schemes. However, employment dynamics are more volatile with defined benefits.

A general insight of this paper is that demographic change may well cover a substantial part of its own financing burden, if labor market imperfections are taken into account. Furthermore, if demographic change induced labor demand is less severe than in the calibrated economy, the contribution rate may even decrease in order to cover the financing burden. This had the side effect that the potentially distorting effects of income related contribution rates have a lower impact on the economy as a whole. Furthermore, social security systems with defined contributions could be less affected by volatile transition dynamics.

Appendix A

A unique solution of equation (20) is obtained, if the absolute value of the wage elasticity of labor demand is higher than or equal to the wage mark up: $-\frac{dn}{dw} \frac{w}{n} \geq \mu$. This necessary condition is fulfilled for $0 < \alpha \leq 0.63$. In the case of $1 > \alpha > 0.63$, more than one solution may be feasible, which is excluded in the following. Rewriting the government's budget (20) yields

$$(1 - \tau)^{1-\alpha} (1 + \tau(\mu - 1))^\alpha = \left(\frac{1 + \frac{\pi}{1+x}}{k} \right)^\alpha \frac{b\mu}{A(1-\alpha)} \quad (30)$$

Figure 3 illustrates the existence of a unique solution of the government's budget. In the upper quadrant it depicts the left-hand-side (LHS) as well as the right-hand-side (RHS) of equation (30). While the RHS takes a constant value, the LHS is non-linear in τ . For the assumed range of α , the value of the LHS is falling with an increasing contribution rate. The lower quadrant shows the aggregate labor demand (18), which depends on τ . For the unique contribution rate that balances the budget, it gives the corresponding equilibrium employment rate.

Lemma 1. *The government's budget (30) solves for a unique value of the contribution rate τ , if the output elasticity of capital is in the range of $0 < \alpha \leq 0.63$.*

Proof. The LHS of equation (30) is given by

$$LHS = (1 - \tau) \left(\frac{1 + \tau(\mu - 1)}{1 - \tau} \right)^\alpha$$

Taking the derivative with respect to τ yields

$$\frac{dLHS}{d\tau} = (1 - \tau) \alpha \left(\frac{1 + \tau(\mu - 1)}{1 - \tau} \right)^{\alpha-1} \frac{\mu}{(1 - \tau)^2} - \left(\frac{1 + \tau(\mu - 1)}{1 - \tau} \right)^\alpha < 0$$

$$(1 - \tau) (\alpha\mu - 1 - \tau(\mu - 1)) < 0$$

If $\alpha\mu - 1 - \tau(\mu - 1) \leq 0$, the LHS of equation (30) is a decreasing function of the contribution rate. This necessary condition is fulfilled for

$$\frac{\alpha\mu - 1}{\mu - 1} \leq \tau$$

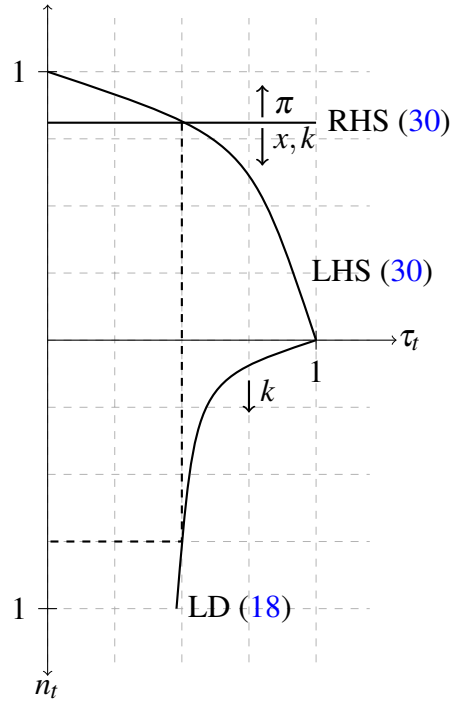


Fig. 3 Aggregate labor market equilibrium

which in turn holds true for any value of $0 < \alpha \leq 0.63$ or $\mu \leq 1/\alpha$. For $RHS < 1$ then, the decreasing LHS and the constant RHS take the same values for a unique $0 < \tau < 1$, which balances the government's budget (30). ■

Appendix B

Period	π	$1+x$	s	k	r	n	τ	b	w	u_y
-3	0.30	0.75	1.885	2.513	2.034	0.7717	0.4000	9.709	19.764	3.257
-2	0.30	0.75	1.885	2.513	2.034	0.7717	0.4000	9.709	19.764	3.257
-1	0.30	0.75	2.409	2.513	2.034	0.7717	0.4000	9.709	19.764	3.625
0	0.45	0.75	2.433	3.212	1.694	0.8251	0.4347	9.709	20.975	3.635
1	0.45	0.75	2.431	3.244	1.666	0.8204	0.4376	9.709	21.085	3.634
2	0.45	0.75	2.431	3.241	1.668	0.8208	0.4373	9.709	21.075	3.634
3	0.45	0.75	2.431	3.242	1.668	0.8207	0.4374	9.709	21.076	3.634
4	0.45	0.75	2.431	3.242	1.668	0.8207	0.4374	9.709	21.076	3.634

Table 3 DB. Simulation results. Longevity driven aging.

Period	π	$1+x$	s	k	r	n	τ	b	w	u_y
-3	0.30	0.75	1.885	2.513	2.034	0.7717	0.4000	9.709	19.764	3.257
-2	0.30	0.75	1.885	2.513	2.034	0.7717	0.4000	9.709	19.764	3.257
-1	0.30	0.75	1.726	2.513	2.034	0.7717	0.4000	9.709	19.764	3.220
0	0.30	0.50	1.732	3.452	1.497	0.7910	0.4558	9.709	21.788	3.224
1	0.30	0.50	1.732	3.464	1.487	0.7893	0.4568	9.709	21.830	3.224
2	0.30	0.50	1.732	3.463	1.488	0.7895	0.4567	9.709	21.826	3.224
3	0.30	0.50	1.732	3.463	1.488	0.7895	0.4567	9.709	21.826	3.224
4	0.30	0.50	1.732	3.463	1.488	0.7895	0.4567	9.709	21.826	3.224

Table 4 DB. Simulation results. Fertility driven aging.

Period	π	$1+x$	s	k	r	n	τ	b	w	u_y
-3	0.30	0.75	1.885	2.513	2.034	0.7717	0.4000	9.709	19.764	3.257
-2	0.30	0.75	1.885	2.513	2.034	0.7717	0.4000	9.709	19.764	3.257
-1	0.30	0.75	2.415	2.513	2.034	0.7717	0.4000	9.709	19.764	3.644
0	0.45	0.75	2.561	3.220	1.812	0.8819	0.4000	10.085	20.530	3.711
1	0.45	0.75	2.611	3.414	1.704	0.8819	0.4000	10.285	20.936	3.734
2	0.45	0.75	2.628	3.482	1.669	0.8819	0.4000	10.352	21.073	3.741
3	0.45	0.75	2.634	3.504	1.657	0.8819	0.4000	10.374	21.119	3.744
4	0.45	0.75	2.636	3.512	1.654	0.8819	0.4000	10.382	21.134	3.744

Table 5 DC. Simulation results. Longevity driven aging.

Period	π	$1+x$	s	k	r	n	τ	b	w	u_y
-3	0.30	0.75	1.885	2.513	2.034	0.7717	0.4000	9.709	19.764	3.257
-2	0.30	0.75	1.885	2.513	2.034	0.7717	0.4000	9.709	19.764	3.257
-1	0.30	0.75	1.733	2.513	2.034	0.7717	0.4000	9.709	19.764	3.241
0	0.30	0.50	1.883	3.465	1.678	0.8819	0.4000	10.335	21.039	3.332
1	0.30	0.50	1.936	3.765	1.533	0.8819	0.4000	10.626	21.631	3.363
2	0.30	0.50	1.954	3.871	1.487	0.8819	0.4000	10.725	21.832	3.373
3	0.30	0.50	1.960	3.907	1.471	0.8819	0.4000	10.758	21.899	3.376
4	0.30	0.50	1.962	3.919	1.466	0.8819	0.4000	10.769	21.921	3.377

Table 6 DC. Simulation results. Fertility driven aging.

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