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Population ageing and labor market frictions. An OLG model applied to Lebanon

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Abstract

We evaluate the effects of population ageing on the macroeconomic evolution of the Lebanese economy and on the financial sustainability of its major pension schemes. We use an OLG model with labor market frictions in the as in de la Croix et al. (2013). Individuals are differentiated by age, gender, and education and choose the sector of activity, which implies that the size of the informal sector is endogenous. We assess the long-run implications of population ageing and show that the public sector pension scheme is unsustainable while the private sector scheme is insufficient to ensure decent living standards for the elderly. Finally, we evaluate the effects of two pension reforms; in the first one we propose a mix of measures aiming at guaranteeing the sustainability of the public sector scheme; in the second one we propose some measures aiming at increasing the size of the private sector scheme.

Keywords: Pensions; Population ageing; OLG models; Labor market frictions.

JEL codes: J11, E62, H55.

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1. Introduction

The population is ageing not only in developed countries but also in developing countries because of the simultaneous fall in fertility and mortality rates. It is well-known that population ageing has dramatic macroeconomic effects that deserve to be evaluated in a comprehensive setting in order to take into account for the general equilibrium linkages between the economic agents (firms, households, the government) and the markets (goods markets, labor market, capital market). Simulation OLG models have been extensively used in the literature to analyze the effects of population ageing in developed countries[1] while only few works apply to developing countries.[2]

The objective of this article is to analyze the effects of population ageing on the macroeconomic evolution of the Lebanese economy, on the functioning of its labor market and on the sustainability of its two major pension schemes. The Lebanese case is very interesting for several reasons. The first reason is that the Lebanese labor market, as in other developing economies, is characterized by the presence of a large informal sector, a low labor participation of women and a high unemployment rate in particular for highly educated people because of the lack of appropriate employment opportunities. The second reason is that the Lebanese social security system combines a PAYG system (that covers the public sector employees) with a funded system (that covers the private sector employees and that pays upon retirement a unique lump-sum payment instead of monthly pensions). In addition, the size of the Lebanese social security system is quite small, even compared to other developing countries: in 2014, pension expenditures on public sector schemes represent 3% of GDP, while the average of emerging economies is 5.8% of GDP (Jarmuzek and Nakhle, 2018). The third reason is that Lebanon is facing a demographic transition

[1] For instance, Eggertson et al. (2019) and Cooley and Henriksen (2018) show that population ageing could explain the low interest rate level and the slowdown in the growth of GDP per person in developed countries. Börsch-Supan et al. (2014) focus on European countries and analyze the effects of demographic changes on the economic growth, savings and international capital flows. Ludwig et al. (2012) analyze the effect of population ageing on the labor supply and human capital decisions.

[2] Loumrhari (2014) for Morocco; Abdessalem and Chekki (2016) for Tunisia; Georges and Seckin (2016) for Turkey.

that will strongly affect the structure of the population in the next decades and will put pressure on the financing of the social security system.

Our analysis is carried out using a simulation OLG model of the type of Auerbach and Kotlikoff (1987). With respect to standard OLG models existing in the literature, our model considers search and matching frictions in the labor market as in de la Croix et al. (2013). However, with respect to de la Croix et al. (2013), the matching function is defined for each education level and sector of activity. As in Charlot and Decreuse (2005), this allows us to differentiate the probability to find a job and to hire a worker by education level and, thus, to take into account the difficulty to find a job for highly educated people, which is an important characteristic of the labor market in developing countries. In addition, the probabilities to find a job and to hire a worker are differentiated by the sector of activity. Zenou (2008) states that, while the formal labor market in developing countries is characterized by the presence of search and matching frictions, the informal sector is competitive, implying that any person searching for an informal job can immediately be employed because of wage flexibility. In contrast, following Charlot et al. (2015), we assume that the informal sector is also frictional, although it is easier to find an informal job than a formal job. Finally, we assume that individuals choose the sector of activity (public, private or informal) in which they supply labor. The choice is assumed to be made on the basis of the relative attractiveness of each sector. This allows us to endogenize the size of the informal sector.

Our OLG model is calibrated in order to reproduce the main features of the Lebanese economy observed in the recent years and is used to evaluate the effects on the sustainability of the existing pension schemes (public and private) and on the macroeconomic dynamic of the country. The simulation results show that the public sector pension scheme is unsustainable since the system will produce extremely high deficits in the next decades. In contrast, the private sector pension scheme can be considered as sustainable, although the generosity of the system is extremely low. In addition, population ageing has negative macroeconomic effects as it reduces the economic

growth rate and the ratio of investments to GDP. The only positive macroeconomic effect is the expected decrease in the unemployment rate thanks to the rise in the marginal productivity of labor and the fall in the interest rate, which induce firms to post more vacancies. Then, we evaluate the effects of an alternative scenario in which we propose a combination of reforms aiming at guaranteeing the sustainability of the public sector pension scheme by correcting its strong weaknesses. In particular, our proposed reform combines (i) an increase in the contribution rate to 25% (while today is only 6%), (ii) a reduction in the maximum replacement ratio from 85% to 70% in 2025 and, gradually, to 50% after 20 years, (iii) a gradual removal of early retirement before age 60, (iv) a gradual elimination of survivor's pensions for women aged less than 55 years. Concerning the private sector pension system, we evaluate the effects of different reforms aiming at increasing its size and, consequently, at improving the standards of living of the elderly: (i) the increase in the contribution rate (paid by the employers and/or by the employees), (ii) the transition of the current funded system toward a PAYG system.

The article is organized as follows. Section 2 describes the demographic evolution, the pension schemes and the labor market in Lebanon. In section 3, we describe the OLG model used in our analysis. In section 4, we describe the calibration procedure and, in section 5, we present our simulation results. Section 6 concludes.

2. Some characteristics of the Lebanese economy

2.1 The demographic evolution in Lebanon

The demographic data used in our article come from the United Nations (World Population Prospects: The 2019 Revision) that provide a comprehensive overview of the Lebanese population, specified by age and gender, from 1950 to 2100. The main features of the Lebanese population transition are summarized in table 1. First, the Lebanese population has strongly increased between

1950 and 2000 (from 1.3 million to 3.8 million) and would increase until 2020 to reach 6.8 million. Then, according to the United Nations projections, the total population would decrease and reach 5.7 million in 2100. Table 1 also shows the strong decline in fertility rates: the fertility rate was 5.7 children per woman in 1950 and is expected to decline over the next decades. According to the United Nations projections, the fertility rate will always be lower than the level that guarantees the generational renewal. Life expectancy at birth has strongly increased between 1950 and 2015 from 62.2 to 80.8 for women and from 58.9 to 77 for men. According to the United Nations projections, life expectancy would progressively increase and reach 90.3 for women and 88 for men in 2100. The evolution of the old-age dependency ratio clearly summarizes the population-ageing problem that the Lebanese economy will face in the next decades. As shown in figure 1, the old-age dependency ratio (computed as the ratio between the number of people aged 65 and over and the number of people aged 15-64) would increase in a spectacular way starting from 2025: it was equal to 9.4% in 2010, it would attain 33% in 2050, 50% in 2075 and 62% in 2100.

2.2 The Lebanese pension system

The Lebanese pension system is characterized by the coexistence of several schemes that are differentiated according to the method of financing and the computation rules of the benefits. In our article, we focus on the two main schemes, i.e. the public sector pension system and the private sector pension system.[3]

The public sector pension scheme is a PAYG system with defined-benefit pensions and covers civil and military servants. The maximum retirement age is 64 for civil servants and between 58 and 64, depending on the rank, for military servants. The pension contribution rate is 6% and

[3] For a detailed description of the Lebanese pension system, see Robalino (2005), Rached (2012) and Jarmuzek and Nakhle (2018).

contributions are paid only by the employees. The lifetime pension is computed on the basis of a 2.125% accrual rate. The maximum replacement rate, obtained after 40 years of service, is 85% of the final salary. As noted by Marwan (2016), the system is characterized by different distorting mechanisms: (i) an extra lump-sum payment is allowed for the retirees with more than 40 years of service; (ii) additional years of service are accounted for military servants; (iii) survivor's pensions are exceptionally generous: unmarried, divorced and widowed daughters of retirees keep the full pension benefits for life. The survivor's pensions received by women represent a large fraction of total pensions: in 2012, the number of pensions received by women aged 45 or less represents 14% of the total and accounts for 17% of the total pension expenditure in the public sector (Ministry of Finance, 2012). In addition, early retirement is very common in the public sector pension system: in 2012, the number of pensions received by men aged between 46 and 64 represents 34% of the total and accounts for 29% of the total pension expenditure in the public sector (Ministry of Finance, 2012).

The private sector pension scheme is a funded system administered by the National Social Security Fund (NSSF)[4] that covers private sector employees. Individuals with at least 20 years of service can retire if they have reached age 60 and the maximum retirement age is 64. The private sector pension system is a special case since private employees receive upon retirement an end-of-service indemnity (instead of monthly pensions) corresponding to the accumulated contributions. Contributions are accumulated in individual accounts and paid only by the employers on the basis of a contribution rate set to 8.5%. The rate of return on contributions is close to the rate on government bonds as NSSF assets are generally invested in Treasury bonds. The inadequacy of the private sector pension scheme is explained by the following reasons: first, the low levels of the coverage rate and of the contribution rate necessarily imply that the size of the private sector

[4] The NSSF is an independent institution established in 1963 and controlled by the Council of Ministers and the Ministry of Labor.

pension system is extremely low (the pension expenditures represent 0.5% of GDP in 2010); second, the funded nature of the pension scheme implies that there is no redistribution across generations in order to protect the most vulnerable people;[5] third, the private sector employees (and their family members) lose their health insurance when they cease to work, i.e. when they need it most.[6]

2.3 The labor market in Lebanon

The Lebanese labor market is characterized by a low labor participation of women, which reflects the existence of family arrangements according to which women leave the labor market once married. As shown in table A1 in Online Appendix 1, the labor participation rate in 2007 was 72.9% for men and 23.9% for women and, on average, 47.6%. Interestingly, the women's labor participation is higher for highly educated women (45%) and extremely low for primary and secondary education levels (between 13% and 19%). For men, the participation rate is higher for those with primary and lower secondary education (78.7% and 76.9%, respectively) than for those with upper secondary education and university levels (59% and 62.5, respectively).

As shown in table A2 in Online Appendix 1, the total unemployment rate is 7.8% in 2004, 9.1% in 2007 and 6.4% in 2009 and is higher for women (9.5% in 2004, 10.1% in 2007 and 10.4% in 2009) than for men (7.3% in 2004, 8.6% in 2007 and 5% in 2009). In addition, the unemployment rate is higher for highly educated people (11.2% in 2007 and 8.8% in 2009), which reflects the difficulty for those people to find a job given the problem of skill mismatch in the labor market. Tables A3 to A7 in Appendix 1 summarize the main characteristics of the micro dataset FEMISE.[7]

[5] The inadequacy of the social security system is partially compensated by the existence of informal transfers from family members and charitable institutions.
[6] According to Rached (2012), more than half of the elderly have difficulties to secure their basic needs.
[7] The dataset FEMISE (Forum *Euro-Méditerranéen des Instituts de Sciences Economiques*, contract FEM3d-03, 2013) is a household survey including a sample of 10,827 individuals. However, after reducing the sample to people aged 15 and over and after controlling for missing values, we retain a total of 6,164 observations.

In particular, the first three tables show the distribution of the people in the sample by age (table A3), education level (table A4) and sector of activity (table A5). Table A6 shows the distribution of people in the sample (differentiated by age and gender) by education level. In particular, the education level decreases with age, especially for women: between 45% and 75% of women aged 70 and over have a preschool level of education while, for men, the share is between 20% and 50%. In contrast, more than the half of men and women aged less than 40 have a secondary education or university levels. This implies that the average level of education was much lower in the past and is likely to be higher in the next decades. Finally, table A7 shows the share of workers by sector of activity (public, private and informal).

The informal sector in Lebanon represents 30% of GDP (International Monetary Fund, 2014) and includes 50% of workers (World Bank, 2012) who are deprived of social protection. The informal sector includes illegal activities and, in most cases, unregistered legal activities that are not accounted in national statistics (Gohlke-Rouhayem et al., 2016).

The Lebanese labor market, as in many other developing countries, is also characterized by a structural mismatch between labor demand and labor supply, which is mainly explained by the inadequacy of the education system's outcomes with respect to labor market needs (European Commission, 2010). In particular, the high level of specialization of recent graduates does not match the needs in terms of skills and qualifications required since the jobs created in recent years have been essentially concentrated in low-productivity sectors that employ mainly low-skilled workers (Abou Jaoude, 2015). The lack of appropriate employment opportunities encourages a high number of graduates to migrate. In addition, given that the Lebanese education system is dominated by the private sector and is very costly, those who remain in the country have a high reservation wage and are discouraged from accepting low-skilled jobs. This contributes to explain the presence of a high level of the unemployment rate among highly educated people.

3. The OLG model with labor market frictions

3.1 General description

The model used in our analysis is a deterministic simulation OLG model of the type of Auerbach and Kotlikoff (1987), similar to that built by de la Croix et al. (2013) who introduced labor market frictions *à la* Pissarides (2000) in simulation OLG models.

In our model, 18 generations coexist at each period and the length of each period is five years. The time horizon of the model is 1960-2300 although, for convenience, the simulation results are reported for the period 2010-2060. Individuals are classified according to their age g, gender s, and education level e. In particular, we consider 18 age groups (1 for individuals aged 15-19, 2 for individuals aged 20-24,…, 18 for individuals aged 100-104), men ($s1$) and women ($s2$), 5 education levels ($e1$ for the preschool level, $e2$ for the primary school level, $e3$ for the intermediate school level, $e4$ for the secondary school level, and $e5$ for the university level). At each period, individuals choose the optimal level of consumption and savings (in order to maximize their well-being given their intertemporal budget constraint) and the sector of activity where to supply labor. We consider 3 sectors of activity c ($c1$ for the public sector, $c2$ for the private sector and $c3$ for the informal sector), where the first two correspond to the Lebanese pension schemes analyzed in our article, while the informal sector concerns individuals who are not covered by the social security system.

A representative firm produces one good in a perfectly competitive market and the labor market is characterized by search and matching frictions. This assumption allows us to endogenize the unemployment rate and to take into account for the tensions in the labor market that make it difficult to find a job, especially for highly educated young people. Regarding the supply side of the labor market, the participation rate (differentiated by age, gender and level of education) is

exogenous[8] while the choice of the sector of activity (public, private or informal) in which individuals supply labor is endogenous. This choice depends on the relative attractiveness of each sector of activity and, in particular, on the wage level paid the sector, the labor tax rate (which is nil in the informal sector) and the level of the pension benefits that the sector will guarantee (which is determined according to different rules in the public and private sector and which is nil in the informal sector). Regarding the demand side of the labor market, the representative firm chooses the optimal level of vacancies in order to maximize the present value of its profits. At each period, some jobs are created (according to a matching function differentiated by education level and sector of activity), other jobs are destroyed (according to an exogenous separation rate) and wages are negotiated through a standard Nash bargaining process.

3.2 Individuals

3.2.1 Demographics

In our model, individuals can live up to 18 periods. The demographic evolution is defined by the following equations:

$$Pop_{g,s,t} = \left(1 + x_{s,t}\right) \cdot Pop_{g,s,t-1} \quad \text{if } g = 1 \tag{1}$$

$$Pop_{g,s,t} = \beta_{g,s,t} \cdot Pop_{g-1,s,t-1} \quad \text{if } g \geq 2 \tag{2}$$

where $Pop_{g,s,t}$ is the number of individuals of age g and gender s; $x_{s,t}$ is a measure of the fertility rate; $\beta_{g,s,t}$ is the conditional probability (differentiated by gender s) of being alive at age g at time t.

[8] Note, however, that the individual participation rate varies over time on the basis of the data observed in 2010. In addition, the fact that the participation rate is exogenous allows us to simulate the effects of an increase in the female participation rate, as we did in a sensitivity analysis.

3.2.2 Labor participation and retirement

Individuals defined in equations 1 and 2 are (exogenously) grouped by education level. The number of individuals of age g, gender s and education level e is noted $N_{g,s,e,t}$ and given by:

$$N_{g,s,e,t} = Pop_{g,s,t} \cdot \varphi_{g,s,e,t} \quad (3)$$

where $\varphi_{g,s,e,t}$ (with $\sum_e \varphi_{g,s,e,t} = 1$ for all g and s) are exogenous parameters that allow to differentiate individuals by education level.

Individuals aged 15-64 (i.e. $g \leq 10$) can either be in the labor force or inactive. The labor participation rate is noted $z_{g,s,e,t}$ and is assumed to be exogenous and differentiated by age, gender and education level. People in the labor force may work or search for a job (in the public sector, or in the private sector or in the informal sector). We note $\vartheta_{g,s,e,c,t}$ (with $\sum_c \vartheta_{g,s,e,c,t} = 1$ for all g, s and e) the (endogenous) share of the labor force who want to work in sector c, $u_{g,s,e,c,t}$ the (endogenous) unemployment rate (differentiated by age, gender, education level and sector of activity) that depends on the frictions in the labor market, and $n_{g,s,e,c,t}$ the (endogenous) employment rate, i.e. the share of people working in sector c. Thus:

$$n_{g,s,e,c,t} = z_{g,s,e,t} \cdot \vartheta_{g,s,e,c,t} \cdot \left(1 - u_{g,s,e,c,t}\right) \quad \text{if } g \leq 10 \quad (4)$$

Given that individuals are either inactive, workers or unemployed, we have that $\left(1 - z_{g,s,e,t}\right) + \sum_c n_{g,s,e,c,t} + \sum_c z_{g,s,e,t} \cdot \vartheta_{g,s,e,c,t} \cdot u_{g,s,e,c,t} = 1$ for all g, s and e.

The number of individuals (by age, gender, education level, sector of activity) earning a pension is:

$$N_{g,s,e,t} \cdot \vartheta^{pens}_{g,s,e,c,t} \quad \text{if } c \leq c_2 \quad (5)$$

where $\vartheta^{pens}_{g,s,e,c,t}$ is the (endogenous) share of individuals earning pension benefits.[9]

[9] Clearly, individuals aged 65 and over ($g \geq 11$) earn pension benefits only if they previously worked in the public sector ($c = c_1$) or in private sector ($c = c_2$). Thus, people who were inactive and people who worked in the informal sector are not covered by the

3.2.3 The individual preferences, budget constraint and choices

Individuals have perfect foresight and choose, at each period, the optimal level of consumption in order to maximize their intertemporal utility given their intertemporal budget constraint. We assume the absence of liquidity constraints. The intertemporal utility function of an individual belonging to the first age group in t, of gender s and education level e is given by:

$$U_{s,e,t} = \sum_{g=1}^{18} \left(\frac{1}{1+\rho}\right)^{g-1} \cdot \ln c_{g,s,e,t+g-1} \cdot \prod_{g'=1}^{g} \beta_{g',s,t+g'-1} \quad (6)$$

where $c_{g,s,e,t}$ is the level of consumption, ρ is the rate of time preference and $\beta_{g,s,t}$ is the conditional probability (differentiated by gender s) of being alive at age g at time t.

The instantaneous budget constraint for all individuals except those belonging to the last age group, i.e. $g < 18$, states that the change in individuals' wealth is given by the difference between incomes (labor and capital incomes, pensions and transfers) and expenditures (consumption and search costs):

$$k_{g+1,s,e,t+1} = \left(1 + r_t \cdot (1-\tau_t)\right) \cdot k_{g,s,e,t} + \sum_c \left(1 - \beta_c^{\tau} \cdot \tau_t - \tau_{c,t}^{w}\right) \cdot w_{e,c,t} \cdot A_{g,s,e,c,t} \cdot n_{g,s,e,c,t}$$

$$+ \sum_c pens_{g,s,e,c,t} \cdot \vartheta_{g,s,e,c,t}^{pens} + transf_{g,s,e,t} - c_{g,s,e,t} - \sum_c search_{g,s,e,c,t}^{h} \cdot \frac{\Omega_{g,s,e,c,t}}{N_{g,s,e,t}} \quad (7)$$

The instantaneous budget constraint for individuals belonging to the last age group ($g = 18$), is:

$$c_{g,s,e,t} = \left(1 + r_t \cdot (1-\tau_t)\right) \cdot k_{g,s,e,t} + \sum_c pens_{g,s,e,c,t} \cdot \vartheta_{g,s,e,c,t}^{pens} \quad (8)$$

In equations 7 and 8, $k_{g,s,e,t}$ is the wealth owned at the beginning of t by individuals aged g, with gender s and education level e; r_t is the interest rate (defined in equation 35); τ_t is the tax rate (on formal labor incomes and capital incomes); β_c^{τ} is a dummy variable equal to 1 for $c \leq c2$ and equal to 0 for $c = c3$, implying that only formal labor incomes are taxed; $\tau_{c,t}^{w}$ is the employees'

pension system. People aged less than 65 ($g \leq 10$) can earn pensions in the public sector (in the case of survivor's pensions for women and in the case of early retirement for men) and in the private sector (in the case of early retirement or change of job).

contribution rate in sector $c \leq c2$; $n_{g,s,e,c,t}$ is the (endogenous) employment rate; $w_{e,c,t} \cdot A_{g,s,e,c,t}$ is the gross wage (differentiated by age, gender, education level and sector of activity) equal to the product of the negotiated wage per unit of effective labor $w_{e,c,t}$ (see section 3.5) and the exogenous productivity level $A_{g,s,e,c,t}$ (differentiated by age, gender, education level and sector of activity) which is supposed to grow over time according to an exogenous rate reflecting the technological progress; $pens_{g,s,e,c,t}$ is the pension benefit in the public sector ($c = c1$) or the end-of-service indemnity in the private sector ($c = c2$); $transf_{g,s,e,t}$ represents the involuntary bequests paid to the children (supposed having 20 years less than their parents); $c_{g,s,e,t}$ is the consumption of goods and services; $search^{h}_{g,s,e,c,t}$ is the (exogenous) cost of searching for a job in the sector of activity c;[10] $\Omega_{g,s,e,c,t}$ (determined in section 3.3.2) is the number of individuals (aged g, with gender s and education level e) who are looking for a job in sector c.

The optimal consumption path is described by the standard Euler equation:

$$\frac{c_{g+1,s,e,t+1}}{c_{g,s,e,t}} = \frac{1+ r_{t+1}\cdot(1-\tau_{t+1})}{1+\rho} \cdot \beta_{g+1,s,t+1} \quad (9)$$

Accordingly, the intertemporal path of consumption depends on the (net of tax) interest rate, the rate of time preference and the conditional probability of being alive in $t+1$ for an individual aged g in t with gender s.

3.2.4 The computation of the pension benefits

The public sector pension scheme ($c = c1$) is a standard PAYG system where the maximum replacement rate (85%) is obtained by people who stop working at age 64 and earn pension benefits

[10] As explained in section 3.3.4, the cost of searching for a job in sector, affects the choice of sector of activity in which individuals choose to work.

starting from age 65 ($g = 11$). Pensions earned before age 65 represent either early retirement pensions for men, or survivor's pensions for women.

Men can earn pension benefits starting from age 45 ($g = 7$) and the amount of the pension is computed as follows:

$$\tilde{P}_{g,s,e,c1,t} = 0.85 \cdot \frac{5 \cdot (g-3)}{40} \cdot w_{e,c,t-1} \cdot A_{g-1,s,e,c1,t-1} \quad \text{if } s = 1 \text{ and } g = 7, \dots, 11 \tag{10}$$

Consequently, the replacement ratio varies from 42.5% for men who earn their first pension in $g = 7$ to 85% for individuals who earn their first pension when aged $g = 11$.

In contrast, for women, we assume that all pensions earned before age 65 are survivor's pensions. Given the lack of information about the deceased relatives, we assume that the amount of the survivor's pension is equal to the average pension earned by men. Concerning working women, we assume that they all stop working at age 64 and earn their first pension at age $g = 11$ on the basis of the maximum replacement rate equal to 85%.

The variable $pens_{g,s,e,c1,t}$ considered in the individual budget constraint (see equations 7 and 8) represents the pension earned at age g and depends on when individuals stop working. In particular, for men aged $g = 7$, $pens_{7,s,e,c1,t}$ coincides with $\tilde{P}_{7,s,e,c1,t}$ since they cannot retire before age $g = 7$. In contrast, for men aged $g = 8$, $pens_{8,s,e,c1,t}$ is computed as the weighted average between $\tilde{P}_{7,s,e,c1,t-1}$ and $\tilde{P}_{8,s,e,c1,t}$, where the weights are given by the share of individuals who retire at age $g = 7$ in $t - 1$ and at age $g = 8$ in t. For men aged $g = 9$, $pens_{9,s,e,c1,t}$ is computed as the weighted average between $\tilde{P}_{7,s,e,c1,t-2}$, $\tilde{P}_{8,s,e,c1,t-1}$ and $\tilde{P}_{9,s,e,c1,t}$, where the weights are given by the share of individuals who retire at age $g = 7$ in $t - 2$, at age $g = 8$ in $t - 1$ and at age $g = 9$ in t. And so on.

For $g \geq 12$, we assume that pensions are indexed on prices and, thus, remain constant over time:

$$pens_{g,s,e,c1,t} = pens_{g-1,s,e,c1,t-1} \quad \text{if } g \geq 12 \tag{11}$$

The private sector pension scheme ($c = c2$) is a fully-funded system that pays an end-of-service indemnity, even in the case of early retirement or change of job. The end-of-service indemnity, for $g = 2, \dots, 11$, is computed by capitalizing past contributions paid by the employers at the rate $\tau^{f}_{c2,t}$:

$$pens_{g,s,e,c2,t} = \sum_{g\prime=1}^{g-1} \tau^{f}_{c2,t+g\prime-g} \cdot w_{e,c,t+g\prime-g} \cdot A_{g\prime,s,e,c2,t+g\prime-g} \cdot \prod_{g\prime\prime=g\prime}^{g-1} \left(1 + \tilde{r}_{t+g\prime\prime-g}\right) \qquad (12)$$

where $\tilde{r}_t$ is the rate of return on contributions (defined in equation 43). Clearly, for $g \geq 12$, the value of the benefit is nil.

3.3 The labor market

The labor market is modeled by taking into account the presence of search and matching frictions which imply that searching for a job for a potential worker and hiring a worker for a firm are costly activities. These frictions prevent the unemployed from immediately finding a job and firms from immediately filling a vacancy.

Regarding the potential workers looking for a job, the labor participation rate is exogenous while the choice of the sector of activity in which they decide to work is endogenous (see section 3.3.4). Except in the public sector, the number of vacant positions is chosen by the representative firm in order to maximize its profit (see section 3.4). The number of jobs created is determined using a matching function (see section 3.3.1) and depends on the number of vacancies and the number of potential workers looking for a job. The matching function is defined separately for each education level and sector of activity. This allows us to differentiate the probability to find a job according to the education level and the economic activity and, consequently, to reproduce the empirical fact that highly educated people have greater difficulties to find a job and that it is easier to find a job in the informal sector. Except for the civil servants who cannot be dismissed, we assume that an exogenous and constant fraction of workers lose their job at the beginning of each period. Except

in the public sector, wages are negotiated at each period according to a standard Nash bargaining procedure (see section 3.5) which allows to share the total surplus between firms and workers according to their respective bargaining power.

3.3.1 The matching functions

The number of jobs created at the beginning of each period, for each education level e and sector c, noted $M_{e,c,t}$, is given by the following matching functions:

$$M_{e,c,t} = c\_match_{e,c} \cdot \left(V_{e,c,t}\right)^{\beta\_match} \cdot \left(\Omega_{e,c,t}\right)^{1-\beta\_match} \quad (13)$$

where, for each education level and sector of activity, $V_{e,c,t}$ is the number of vacancies posted by the representative firm and $\Omega_{e,c,t}$ is the number of individuals searching for a job. The parameters $c\_match_{e,c}$ measure the matching efficiency. The matching functions have the standard properties, i.e. they are continuous, linearly homogeneous, increasing and concave in both of their arguments and satisfy the Inada conditions. The matching functions, as defined in equation 13, imply that potential workers can apply only on the markets for which they have the required skills.

The probability to find a job in sector c for an individual with education e is:

$$p_{e,c,t} = \frac{M_{e,c,t}}{\Omega_{e,c,t}} \quad (14)$$

Thus, this probability is assumed to be the same regardless of the individual's age and gender.

The probability that a vacancy is filled is:

$$q_{e,c,t} = \frac{M_{e,c,t}}{V_{e,c,t}} \quad (15)$$

3.3.2 Number of individuals searching for a job

Concerning people belonging to the first age group ($g = 1$), i.e. individuals who enter the labor market for the first time, the number of those searching for a job in sector c in sector c (by gender and education level) is given by:

$$\Omega_{g,s,e,c,t} = z_{g,s,e,t} \cdot \vartheta_{g,s,e,c,t} \cdot N_{g,s,e,t} \quad \text{if } g = 1 \tag{16}$$

Concerning the other age groups ($g > 1$), we have to analyze the three following cases.

i) $z_{g,s,e,t} \cdot \vartheta_{g,s,e,c,t} = z_{g-1,s,e,t-1} \cdot \vartheta_{g-1,s,e,c,t-1}$, i.e. the participation rate in sector c remains constant. In this case, the number of individuals looking for a job in sector c depends on the number of individuals who were unemployed in the previous period (and are still alive and search for a job in sector c) and on the number of individuals who worked in sector c in the previous period and lose their job at the beginning of the current period. We note $\chi_{e,c}$ the separation rate, which is assumed to be exogenous, constant and independent of the individual's age and gender. However, it is differentiated by education level and sector of activity. In fact, in the public sector, civil servants cannot be dismissed and the separation rate is thus fixed to zero. Then, the number of individuals searching for a job in sector c (by age, gender and education level) is:

$$\Omega_{g,s,e,c,t} = z_{g-1,s,e,t-1} \cdot \vartheta_{g-1,s,e,c,t-1} \cdot u_{g-1,s,e,c,t-1} \cdot N_{g,s,e,t} + n_{g-1,s,e,c,t-1} \cdot \chi_{e,c} \cdot N_{g,s,e,t} \tag{17}$$

ii) $z_{g,s,e,t} \cdot \vartheta_{g,s,e,c,t} > z_{g-1,s,e,t-1} \cdot \vartheta_{g-1,s,e,c,t-1}$. In this case, some additional individuals search for a job in sector c in t (either because they enter the labor market in t or because they change their sector of activity). Thus, the number of individuals searching for a job in sector c (by age, gender and education level) is:

$$\Omega_{g,s,e,c,t} = z_{g-1,s,e,t-1} \cdot \vartheta_{g-1,s,e,c,t-1} \cdot u_{g-1,s,e,c,t-1} \cdot N_{g,s,e,t} \tag{18}$$

$$+\ n_{g-1,s,e,c,t-1} \cdot \chi_{e,c} \cdot N_{g,s,e,t}$$

$$+\ \left(z_{g,s,e,t} \cdot \vartheta_{g,s,e,c,t} - z_{g-1,s,e,t-1} \cdot \vartheta_{g-1,s,e,c,t-1}\right) \cdot N_{g,s,e,t}$$

where the first two components in the RHS of equation 18 are as in the first case; the last one represents the number of individuals who enter the labor market and search for a job in sector c.

iii) $z_{g,s,e,t} \cdot \vartheta_{g,s,e,c,t} < z_{g-1,s,e,t-1} \cdot \vartheta_{g-1,s,e,c,t-1}$. In this case, some individuals stop searching for a job in sector c in t (either because they exit the labor market or because they change their sector of activity). Thus, the number of individuals searching for a job in sector c is:

$$\Omega_{g,s,e,c,t} = z_{g-1,s,e,t-1} \cdot \vartheta_{g-1,s,e,c,t-1} \cdot u_{g-1,s,e,c,t-1} \cdot N_{g,s,e,t} \quad (19)$$

$$+\ n_{g-1,s,e,c,t-1} \cdot \chi_{e,c} \cdot N_{g,s,e,t}$$

$$-\ \left(z_{g-1,s,e,t-1} \cdot \vartheta_{g-1,s,e,c,t-1} - z_{g,s,e,t} \cdot \vartheta_{g,s,e,c,t}\right) \cdot \left(1 - u_{g-1,s,e,c,t-1}\right) \cdot \chi_{e,c} \cdot N_{g,s,e,t}$$

$$-\ \left(z_{g-1,s,e,t-1} \cdot \vartheta_{g-1,s,e,c,t-1} - z_{g,s,e,t} \cdot \vartheta_{g,s,e,c,t}\right) \cdot u_{g-1,s,e,c,t-1} \cdot N_{g,s,e,t}$$

The first two components in the RHS of equation 19 are as in the first case. The third component represents the number of individuals who worked in $t-1$ in sector c, lose their job at the beginning of the current period and do not look for a job in sector c since they become inactive or change their sector of activity. The fourth component represents the number of individuals who were unemployed in $t-1$ and do not look for a job in sector c since they become inactive or search for a job in a different sector of activity.

In a more compact way, for individuals aged $g > 1$, the number of individuals searching for a job can be written as:[11]

$$\Omega_{g,s,e,c,t} = \left[z_{g,s,e,t} \cdot \vartheta_{g,s,e,c,t} - \left(1 - \chi_{e,c}\right) \cdot n_{g-1,s,e,c,t-1} \cdot \mu_{g,s,e,c,t}\right] \cdot N_{g,s,e,t} \quad \text{if } g > 1 \quad (20)$$

with:

[11] The mathematical details are shown in Online Appendix 2a.

$$\mu_{g,s,e,c,t} = \begin{cases} 1 & \text{if } z_{g,s,e,t} \cdot \vartheta_{g,s,e,c,t} \geq z_{g-1,s,e,t-1} \cdot \vartheta_{g-1,s,e,c,t-1} \\ \frac{z_{g,e,s,t} \cdot \vartheta_{g,s,e,c,t}}{z_{g-1,s,e,t-1} \cdot \vartheta_{g-1,s,e,c,t-1}} & \text{if } z_{g,s,e,t} \cdot \vartheta_{g,s,e,c,t} < z_{g-1,s,e,t-1} \cdot \vartheta_{g-1,s,e,c,t-1} \end{cases} \quad (21)$$

The total number of individuals searching for a job (by education level and sector of activity) is:

$$\Omega_{e,c,t} = \sum_{g,s} \Omega_{g,s,e,c,t} \quad (22)$$

This variable is used in the matching functions defined in equation 13.

3.3.3 Number of workers

The number of workers who belong to the first age group is given by the number of individuals who look for a job and find a job with probability $p_{e,c,t}$:

$$L_{g,s,e,c,t} = p_{e,c,t} \cdot z_{g,s,e,t} \cdot \vartheta_{g,s,e,c,t} \cdot N_{g,s,e,t} \quad \text{if } g = 1 \quad (23)$$

Concerning the individuals belonging to the other age groups, the number of workers (by age, gender, education level and sector of activity) is equal to the number of individuals who find a job (among those who look for a job) plus the number of individuals who worked in the previous period and still work in the same sector (since they are still active, don't lose their job and don't change their sector of activity). Then, we subtract the number of individuals who previously worked in sector c and become inactive or change their sector of activity. In a compact form, with $g > 1$:[12]

$$L_{g,s,e,c,t} = \left[p_{e,c,t} \cdot z_{g,s,e,t} \cdot \vartheta_{g,s,e,c,t} + \left(1 - p_{e,c,t}\right) \cdot \left(1 - \chi_{e,c}\right) \cdot n_{g-1,s,e,c,t-1} \cdot \mu_{g,s,e,c,t}\right] \cdot N_{g,s,e,t} \quad (24)$$

The employment rate, which represents the share of people working in sector c (i.e. $n_{g,s,e,c,t} = L_{g,s,e,c,t} / N_{g,s,e,t}$), can be obtained as follows:

[12] The mathematical details are shown in Online Appendix 2b.

$$n_{g,s,e,c,t} = \begin{cases} p_{e,c,t} \cdot z_{g,s,e,t} \cdot \vartheta_{g,s,e,c,t} & \text{if } g = 1 \\ p_{e,c,t} \cdot z_{g,s,e,t} \cdot \vartheta_{g,s,e,c,t} + (1 - p_{e,c,t}) \cdot (1 - \chi_{e,c}) \cdot n_{g-1,s,e,c,t-1} \cdot \mu_{g,s,e,c,t} & \text{if } g > 1 \end{cases} \quad (25)$$

3.3.4 Choice of the sector of activity

As previously mentioned, the participation rate $z_{g,s,e,t}$ is exogenous, while the choice of the sector of activity in which individuals decide to work is endogenous. In particular, we assume that individuals choose in each period the sector of activity by performing a cost-benefit analysis. This choice also concerns individuals who already have a job, who can therefore decide to change their sector of activity.

In the literature (see for example Christensen et al., 2005), the choice of the sector is analyzed by assuming that individuals (who are heterogeneous in terms of productivity) decide to look for another job if the present value of the monetary earnings related to this new job is greater than that obtained with the current job. The hypothesis of individual heterogeneity makes it possible to find a threshold level of productivity that allows to separate individuals who look for a new job from those who keep the same job. In a model with three sectors of activity (public, private and informal), Yassine and Langot (2018) analyze the choice of individuals working in the private sector and in the informal sector of looking for a better job in the public sector. The authors show that this choice depends on the individual's level of productivity and that there is a threshold level of productivity that allows to determine which individuals look for a new job.

Compared to the articles cited above, the same approach cannot be adopted in our model because all the individuals belonging to a given category (by age, gender and education) have the same level of productivity. In order to determine the choice of the sector of activity, we assume that the representative individual (by age, gender and level of education) chooses the optimal share of labor supplied in the sector of activity c according to its relative attractiveness compared to each other

sector c' and, more precisely, by comparing the present discounted value, noted $V^h_{g,s,e,c,t}$, of all the monetary gains obtained throughout the life cycle with an additional job in each sector of activity:

$$\frac{\vartheta_{g,s,e,c,t}}{\vartheta_{g,s,e,c',t}} = \frac{V^h_{g,s,e,c,t}}{V^h_{g,s,e,c',t}} \tag{26}$$

where $V^h_{g,s,e,c,t}$ is computed as follows:

- For individuals aged up to 59 ($g < 10$):

$$V^h_{g,s,e,c,t} = \left(1 - \beta^\tau_c \cdot \tau_t - \tau^w_{c,t}\right) \cdot w_{e,c,t} \cdot A_{g,s,e,c,t} - search^h_{g,s,e,c,t} + \frac{1}{1+r_{t+1}\cdot(1-\tau_{t+1})} \cdot V^h_{g+1,s,e,c,t+1} \cdot \frac{\partial n_{g+1,s,e,c,t+1}}{\partial n_{g,s,e,c,t}} \tag{27}$$

  where $\left(1 - \beta^\tau_c \cdot \tau_t - \tau^w_{c,t}\right) \cdot w_{e,c,t} \cdot A_{g,s,e,c,t}$ is the net wage in sector c, $search^h_{g,s,e,c,t}$ is the (exogenous) cost of searching for a job in sector c and $\frac{\partial n_{g+1,s,e,c,t+1}}{\partial n_{g,s,e,c,t}} = \left(1 - p_{e,c,t+1}\right) \cdot \left(1 - \chi_{e,c}\right) \cdot \mu_{g+1,s,e,c,t+1}$ (from equation 25) is the effect of this additional job on the future employment rate.

- For individuals aged 60-64 ($g = 10$) :

$$V^h_{g,s,e,c,t} = \left(1 - \beta^\tau_c \cdot \tau_t - \tau^w_{c,t}\right) \cdot w_{e,c,t} \cdot A_{g,s,e,c,t} - search^h_{g,s,e,c,t} + \frac{1}{1+r_{t+1}\cdot(1-\tau_{t+1})} \cdot V^h_{g+1,s,e,c,t+1} \tag{28}$$

- For individuals aged 65 and over ($g > 10$) :

$$V^h_{g,s,e,c,t} = pens_{g,s,e,c,t} + \frac{1}{1+r_{t+1}\cdot(1-\tau_{t+1})} \cdot V^h_{g+1,s,e,c,t+1} \tag{29}$$

The previous equations imply that the choice of the sector of activity depends on the gross wage (which is different in the three sectors of activity), on the tax rate on labor income (which is nil in the informal sector), on the employee contribution rate (which is nil in the private sector and in

the informal sector), and on the level of the pension benefits (which is calculated with different rules in the public and private sector and is nil in the informal sector).

3.4 The representative firm and the choice of the number of vacancies

The technology of the representative firm is described by the following production function:

$$Y_t = K_t^{\alpha} \cdot \left(\sum_c (\alpha_c)^{1/\sigma} \cdot \left(Z_{c,t}\right)^{\frac{\sigma-1}{\sigma}} \right)^{1-\alpha} \quad (30)$$

where K_t is the capital employed and $Z_{c,t}$ is the number of units of effective labor employed in each sector of activity c. Equation 30 implies first that the capital stock K_t and the aggregate labor are substitutable with unit elasticity, as in a standard Cobb-Douglas function (where α is the income share of capital). Then, equation 30 implies that the units of effective labor employed in each sector of activity are imperfectly substitutable (where σ represents the elasticity of substitution between these inputs), which implies that they do not contribute to GDP in the same way. [13] The number of units of effective labor employed in each sector of activity is defined as follows:

$$Z_{c,t} = \sum_{g,s,e} A_{g,s,e,c,t} \cdot N_{g,s,e,t} \cdot n_{g,s,e,c,t} \quad (31)$$

At each period, the representative firm chooses the demand of capital and the number of vacancies (by education level and sector of activity). In the private sector and the informal sector, the number of vacancies is chosen in order to maximize the value of the firm, given the technological constraint

[13] A sensitivity analysis is carried out to prove that this hypothesis is not fundamental. In this analysis, we assume that the units of effective labor employed in each sector of activity are perfectly substitutable, i.e. $Y_t = K_t^{\alpha} \cdot Z_t^{1-\alpha}$, where the total number of units of effective labor is $Z_t = \sum_{g,s,e,c} A_{g,s,e,c,t} \cdot N_{g,s,e,t} \cdot n_{g,s,e,c,t}$. We find that the hypothesis used in our model does not alter the simulation results. The results are available from the authors upon request.

(equation 30) and the probability that a vacancy is filled (equation 15). In contrast, in the public sector, the number of vacancies is assumed to be determined without optimization principles.

The value of the firm, noted W_t, is defined as the present discounted value of all current and future profits:

$$W_t = \sum_{t'=t}^{\infty} \frac{\pi_{t'}}{\prod_{t''=t+1}^{t'} (1+r_{t''})} \quad (32)$$

where profits, noted π_t, are given by the difference between the sales revenues and the production costs:

$$\pi_t = Y_t - rr_t \cdot K_t - \sum_{g,s,e,c} w_{e,c,t} \cdot A_{g,s,e,c,t} \cdot \left(1 + \tau_{c,t}^{f}\right) \cdot N_{g,s,e,c,t} \cdot n_{g,s,e,c,t} \quad (33)$$

$$- \sum_{e,c} search_{e,c,t}^{f} \cdot V_{e,c,t}$$

where rr_t is the rental price of capital, $\tau_{c,t}^{F}$ is the employers' contribution rate (which is nil in the informal sector and in the public sector pension scheme), and $search_{e,c,t}^{f}$ is the (exogenous) vacancy cost assumed to grow over time at a rate equal to the productivity growth rate.

The first-order condition for profit maximization concerning the optimal demand of capital states that the rental price of capital must be equal to its marginal productivity:

$$rr_t = \frac{\partial Y_t}{\partial K_t} \quad (34)$$

The interest rate is defined as the marginal gain from an additional unit of capital and is given by the sum between the rental price of capital net of depreciation (where δ is the depreciation rate) and the profit rate computed as the ratio between dividends π_t and the capital stock K_t:

$$r_t = rr_t - \delta + \frac{\pi_t}{K_t} \quad (35)$$

For the representative firm, the value $V_{g,s,e,c,t}^{f}$ of an additional job (differentiated by age, gender, education level and sector of activity) represents the increase in the value of the firm induced by

the additional job and is computed as the present discounted value (until the retirement age) of all the differences between the marginal productivity of labor and the labor cost, and considering the probability that this additional job can be destroyed in the future:

$$V^{f}_{g,s,e,c,t} = \frac{\partial Y_t}{\partial Z_{c,t}} \cdot A_{g,s,e,c,t} - w_{e,c,t} \cdot A_{g,s,e,c,t} \cdot \left(1 + \tau^{f}_{c,t}\right) + \frac{1}{1+r_{t+1}} \cdot V^{f}_{g+1,s,e,c,t+1} \cdot \left(1 - \chi_{e,c}\right) \quad (36)$$

The first-order condition for profit maximization concerning the optimal number of vacancies by education level and sector of activity (except in the public sector) states that the marginal revenue for an additional vacancy must be equal to its marginal cost:

$$search^{f}_{e,c,t} = q_{e,c,t} \cdot \sum_{g,s} \frac{\Omega_{g,s,e,c,t}}{\Omega_{e,c,t}} \cdot V^{f}_{g,s,e,c,t} \quad (37)$$

where the marginal revenue is given by the average increase in the value of the firm induced by an additional job and weighted by the probability that the vacancy is filled, while the marginal cost is given by the search cost.

In contrast, in the public sector, we assume that the number of vacancies evolves over time on the basis of the size of the population:

$$V_{e,c1,t} = V_{e,c1,t-1} \cdot \frac{\sum_{g,s} Pop_{g,s,t}}{\sum_{g,s} Pop_{g,s,t-1}} \quad (38)$$

which implies that a larger population requires additional public services and a larger number of civil servants.

3.5 Wage bargaining

The wage per unit of effective labor is assumed to be negotiated at each period, for each level of education and sector of activity (except the public sector), through a standard Nash-bargaining process. In particular, it is determined in order to maximize the total surplus defined as:

$$\left[\sum_{g,s} \frac{\Omega_{g,s,e,c,t}}{\Omega_{e,c,t}} \cdot V^{f}_{g,s,e,c,t}\right]^{1-\eta} \cdot \left[\sum_{g,s} \frac{\Omega_{g,s,e,c,t}}{\Omega_{e,c,t}} \cdot V^{h}_{g,s,e,c,t}\right]^{\eta} \quad (39)$$

The solution of the maximization problem is the following:

$$\eta \cdot \sum_{g,s} \frac{\Omega_{g,s,e,c,t}}{\Omega_{e,c,t}} \cdot V^{f}_{g,s,e,c,t} = (1-\eta) \cdot \sum_{g,s} \frac{\Omega_{g,s,e,c,t}}{\Omega_{e,c,t}} \cdot V^{h}_{g,s,e,c,t} \quad (40)$$

Thus, the wage per unit of effective labor, for each education level and sector of activity (except the public sector), is determined by sharing the total surplus created by an additional job between the representative firm and the workers, according to their respective bargaining weights. In the public sector, instead, we assume the absence of negotiations and that the wage per unit of effective labor is constant.

3.6 The pension system

For the public sector pension scheme ($c = c1$) and the private sector pension scheme ($c = c2$), the budget surplus is defined as the difference between the contributions earned and the pensions paid:

$$S^{pens}_{c,t} = \left(\tau^{w}_{c,t} + \tau^{f}_{c,t}\right) \cdot \sum_{g,s,e,c} w_{e,c,t} \cdot A_{g,s,e,c,t} \cdot n_{g,s,e,c,t} \cdot N_{g,s,e,t} \quad (41)$$

$$- \sum_{g,s,e,c} pens_{g,s,e,c,t} \cdot N_{g,s,e,t} \cdot \vartheta^{pens}_{g,s,e,c,t}$$

In the fully-funded private sector pension scheme, the evolution of pension reserves, noted $Res_{c2,t}$, is given by:

$$Res_{c2,t+1} = Res_{c2,t} \cdot (1 + \tilde{r}_t) + S^{pens}_{c2,t} \quad (42)$$

where $\tilde{r}_t$ is the rate of return on government bonds. In the model, we assume that physical capital and government bonds are not perfectly substitutable, which implies that their returns are

different.[14] In particular, the interest rate on government bonds $\tilde{r}_t$ is computed as the difference between the interest rate (defined in equation 35) and a spread, noted π^r:

$$\tilde{r}_t = r_t - \pi^r \quad (43)$$

where the spread is assumed to be exogenous and is calibrated in order to reproduce the rate of return on government bonds observed in 2010.

3.7 The government

We assume that the ratio between public purchases, noted G_t, and GDP is exogenous and constant:

$$\frac{G_t}{GDP_t} = \alpha_g \quad (44)$$

where GDP is defined as the value of output net of search costs paid by the representative firm and by the individuals searching for a job:

$$GDP_t = Y_t - \sum_{c,e} search^f_{e,c,t} \cdot V_{e,c,t} - \sum_{g,s,e,c} search^h_{g,s,e,c,t} \cdot \Omega_{g,s,e,c,t} \quad (45)$$

The public sector pension scheme is assumed to be consolidated into the government account. The public surplus, noted S^G_t, depends on the surplus of the public sector pension scheme, tax revenues (taxes on formal labor incomes and capital incomes) and public purchases:

$$S^G_t = \tau_t \cdot \sum_{g,s,e,c} \left(\beta^\tau_c \cdot w_{e,c,t} \cdot A_{g,s,e,c,t} \cdot n_{g,s,e,c,t} \cdot N_{g,s,e,t} + r_t \cdot k_{g,s,e,t} \cdot N_{g,s,e,t}\right) + S^{pens}_{c1,t} - G_t \quad (46)$$

The evolution of the public debt, noted B_t, is given by:

$$B_{t+1} = B_t \cdot (1 + \tilde{r}_t) - S^G_t \quad (47)$$

We assume that the pension reserves of the private scheme are used to finance the public debt:

[14] More precisely, physical capital is assumed to be held only by households while public bonds are assumed to be held only by the private pension fund.

$$Res_{c2,t} = B_t \quad (48)$$

The tax rate τ_t is endogenously determined in order to satisfy equation 48.

3.8 The market equilibrium

The market clearing condition in the capital and in the goods markets are:

$$K_t = \sum_{g,s,e} k_{g,s,e,t} \cdot N_{g,s,e,t} \quad (49)$$

$$GDP_t = \sum_{g,s,e} c_{g,s,e,t} \cdot N_{g,s,e,t} + I_t + G_t \quad (50)$$

4. Model calibration

The model is calibrated in two steps. In the first step, the model is calibrated in steady state implying that the economy, in the absence of economic and demographic shocks, is on its balanced growth path. Table 2 shows the main parameters used in the calibration. First of all, we determine the value of the parameters $A_{g,s,e,c,t}$ for the year 2010. To this, we use the dataset FEMISE and we estimate the wage equation for the three sectors of activity (public, private and informal sectors).[15] The value of the parameters $A_{g,s,e,c,t}$ for the other periods is computed by considering an annual productivity growth rate equal to 1.5%. The annual depreciation rate is 3%. The exponent α in the production function is 0.2[16] while the elasticity of substitution between the units of effective labor employed in the sectors of activity is set to 3. The annual spread is fixed to 3.1%. This value has been computed in order to reproduce an annual rate of return on government bonds equal to 4% in 2010. Concerning the labor market, the separation rate in the private and the informal sectors is

[15] The estimation results are reported in table A8 in Online Appendix 1.
[16] Note, however, that given the presence in the model of profits and vacancy costs, the labor share of GDP is less than 80%. For instance, in 2010, the labor share of GDP is 68%.

assumed to be equal to 60% for low educated workers and to 40% for high educated workers. In the public sector, the separation rate is set to zero since civil servants cannot be dismissed. As in de la Croix et al. (2013), the exponent in the matching functions β_match is set to 0.5 and the parameter that measures the bargaining power of workers η is set to 0.5.

Once the OLG model is calibrated in steady state, in the second step of our calibration we introduce the following shocks: (i) the demographic shock; (ii) the change in the composition of the population by education level; (iii) the change in the labor participation rates. In particular, the demographic shock (i.e. the change in fertility rates $x_{s,t}$ and in survival probabilities $\beta_{g,s,t}$) is based on the demographic data and projections provided by the United Nations (World Population Prospects: The 2019 Revision). Concerning the second shock, we use the micro dataset FEMISE to determine, for the year 2010, the value of the parameters $\varphi_{g,s,e,t}$ (see equation 3). The value of these parameters for the other periods is computed by projecting (forward and backward) the data observed in 2010. As shown in figure 2, the composition of the population by education level will be strongly modified during the demographic transition. The share of low educated people (preschool level and primary school level) is expected to decrease significantly in the next decades, while the share of highly educated people with a secondary school level should strongly increase. Interestingly, the share of people with a university level is expected to slightly decrease over time. This situation is explained by the fact that highly educated young people are more likely to migrate. Concerning the third shock, the value of the parameters $z_{g,s,e,t}$ is determined using the data provided by the Central Administration for Statistics (CAS) that report, for the year 2009, the labor participation rates differentiated by age, gender and education level. The value for the other periods is computed by projecting (forward and backward) the data observed.

These shocks are introduced as exogenous in the model and constitute our base scenario, the results of which are discussed in section 5.1. The second step of our calibration procedure consists in determining the value of some parameters and exogenous variables such that the results obtained

in the base scenario reproduce, for the year 2010, (i) the main macroeconomic variables (GDP and its components), (ii) the key labor market variables (employment rates and unemployment rates at the aggregate level and differentiated by age, gender and education level) and (iii) the main variables concerning the two pension schemes (number of contributors, number of retirees, pension expenditures and contributions). In particular, the matching efficiency ($c\_match_{e,c}$) and the vacancy costs ($search^{f}_{e,c,t}$) are calibrated in order to reproduce the observed unemployment rates in 2010 for each education level and to obtain reasonable results in terms of probabilities to find a job, i.e. to reproduce the fact that the probability to find a job is higher in the informal sector than in the formal sector (public or private) and that high educated people have a lower probability to find a job in the private and the informal sectors than low educated people. The parameters $search^{h}_{g,s,e,c,t}$, which represent the search cost paid by individuals looking for a job in sector c, have been calibrated, for the year 2010, so as to reproduce the share of individuals (aged g, with gender s and education level e) who work in each sector of activity observed in the FEMISE database. For the other periods, these parameters increase over time according to the productivity growth rate.

In tables 3a, 3b and 3c, we compare, for some relevant variables, the data observed in 2010 with those generated, for the same year, by the base scenario of our OLG model. We show that our calibration procedure is quite accurate in reproducing observed data at the macroeconomic level and for the two pension schemes. Finally, table A9 in Online Appendix 1 shows the model results, for the year 2010, for some labor market variables (labor participation, unemployment, informality, etc.) at the national level and by age, gender and education level.

5. Simulation results

5.1 The base scenario

In this section, we present the results of the base scenario that evaluates the effects of the demographic shocks, assuming that no policy reforms will be undertaken. The main macroeconomic results are summarized in table 4. As in standard OLG models, we find that population ageing raises the capital per unit of effective labor.[17] Indeed, the negative effect of the demographic shock on labor supply dominates the negative effect on capital accumulation (explained by the fall in the investment-to-GDP ratio), which implies an increase in the capital per unit of effective labor. The raise in the capital per unit of effective labor negatively affects the marginal productivity of capital, which explains the fall in the interest rate. The tax rate (on formal labor incomes and capital incomes) will increase sharply in order to meet the government's budget constraint given the high deficits generated by the public sector pension scheme. Although individuals are induced to save more because of the increase in life expectancy, aggregate savings decline. This implies a sharp drop in the investment-to-GDP ratio (from 20% observed in 2010 to less than 10% after 2050) that negatively affects the accumulation of capital. Clearly, the evolution of the supply of capital and of labor will have negative consequences on the economic growth. As shown in table 4, the growth rate of GDP and GDP per person will drop sharply over the coming decades.

Regarding the labor market, the demographic shock first affects the number of individuals searching for a job (which depends on the number of working-age individuals and on their participation in the labor market). As shown in table 5, labor participation increases over the time for both men and women and at the aggregate level. The choice of the sector of activity is mainly affected by the upward trend of the tax rate which makes formal jobs less attractive. Indeed, as

[17] In the model, the capital per unit of effective labor is $K_t \,/\, \sum_c (\alpha_c)^{1/\sigma} \cdot \left(Z_{c,t}\right)^{\frac{\sigma-1}{\sigma}}$.

shown in table 5, the share of individuals who choose the informal sector tends to increase over time for all levels of education. Another reason why the private sector becomes less attractive is the fall in the interest rates. In fact, the fall in the interest rates reduces the value of the end-of-service indemnity paid by the private sector pension scheme, which explains the reduction in the share of people choosing the private sector. Second, the demographic shock affects the marginal productivity of labor and, consequently, the negotiated wages. As shown in table 6, the marginal productivity of labor increases in all the economic sectors. Starting from 2040, the positive effect is larger in the private sector, which is explained by the fall in the share of individuals who choose to work in the private sector. The increase in the marginal labor productivity induces an increase in the negotiated wage per unit of effective labor for each level of education and sector of activity, (except, of course, in the public sector). In fact, in the public sector, the wage per unit of effective labor is not negotiated and is kept constant. Third, as shown in table 7, the demographic shock has important consequences on employment and unemployment.[18] As in de la Croix et al. (2013), we find that population aging, by increasing the marginal productivity of labor in all the economic sectors (which increases the gain for the representative firm to post more vacancies) and by reducing the interest rate (which increases the present value of the gains related to the creation of vacancies), incite the representative firm to create more vacancies. This implies an increase in the number of new jobs created and, consequently, a decrease in the unemployment rate. As shown in table 7, the unemployment rate at the national level would drop over time (from 6.3% in 2010 to 0.8% in 2050), for both men and women (respectively by 6% in 2010 to 0.7% in 2050 and from 7.4% in 2010 to 1.1% in 2050) and for each level of education. The increase in participation in the labor market, combined with the fall in unemployment, explains the increase in the employment rate. Table 7 also shows the increase in the size of the informal sector, both in terms of number of workers (relative to the total number of workers) and in terms of wage bill (relative to GDP), which

[18] The shock has also important effects on the probability for a potential worker to find a job and the probability for the representative firm to fill a vacancy. These effects are shown in table A10 in Online Appendix 1.

is explained by the fact that the informal sector becomes relatively more attractive with respect to the two formal sectors.

The effects on the two pension schemes are shown in table 8. First, population aging will lead to a sharp increase in the number of retirees and in the ratio between the number of retirees and the number of contributors, for both pension regimes. Clearly, the evolution of the ratio between the number of retirees and the number of contributors reflects the evolution of the old-age dependency ratio. As shown in table 8, the ratio of pension contributions to GDP remains essentially stable for both the public and private sector schemes. On the other hand, the ratio between pension expenditure and GDP increases considerably for the public sector pension scheme (from 3.1% in 2010 to 5.7% in 2050), while it increases more slowly for the private sector pension scheme (from 0.5% in 2010 to 2.1% in 2050). Consequently, the public sector pension system generates extremely high deficits (which would represent 5.3% of GDP in 2050), implying that it is clearly unsustainable. In contrast, the private sector pension system can be considered sustainable. Indeed, the financial surplus (computed by including the interest on the pension fund) is positive throughout the period and pension reserves increase over time and remain positive. However, the private sector pension regime has a major drawback. Indeed, the standard of living of people aged 65 and over is significantly lower compared to that of working-age individuals. This is explained by the fact that the ratio between the average pension (computed as the ratio between the total amount of pensions and the number of individuals aged 65 and over) and the average salary (computed as the ratio between the wage bill and the population aged 15-64) is extremely low (24.5% in 2010). This is explained by the low level of the pension expenditure in the private sector scheme and by the presence of a large share of individuals aged 65 and over who do not receive pensions (due to the large size of the informal sector and the low level of the labor participation rate). In addition, the ratio between the average pension and the average salary is expected to fall

over time (21.9% in 2050), which is mainly explained by the decline in the end-of-service indemnity paid by the private sector pension scheme (due to the fall in the interest rates).[19]

5.2 Pension system reforms

5.2.1 Reform of the public sector pension scheme

In this section, we evaluate the effects of different policy reforms aimed at ensuring the sustainability of the public sector pension system. The simulation results presented in the previous section clearly show that, without appropriate reforms, the public sector pension system is unsustainable. In addition to the fact that the Lebanese population is ageing, this unsustainability is explained by several reasons. The first reason is that the public sector pension scheme is excessively generous: although the contribution rate is only 6%, the replacement rate obtained with 40 years of service is 85%, implying that the implicit rates of return on contributions are excessively high and therefore unsustainable. The second reason is related to the fact that survivor's pensions are exceptionally generous since unmarried, divorced and widowed daughters of retirees keep the full value of pension benefits for life. The third reason is that early retirement is very frequent. For these reasons, we consider a reform including the following changes: i) an increase in the contribution rate to 25% starting from 2025; ii) a reduction in the maximum replacement ratio from 85% to 70% in 2025 and, gradually, to 50% after 20 years; iii) a gradual elimination of early retirement starting from 2025 such that, after 20 years, workers cannot retire before age 60; iv) a gradual elimination starting from 2025 of survivor's pensions for women aged

[19] A sensitivity analysis has been carried out to analyze the impact of an increase in the labor participation of women. Starting from 2025, the participation rate of women has been gradually increased until reaching, after 20 years, the participation rate of men. We find that the increase in the participation rate of women would produce a significant positive effect on the economic growth and a negative effect on unemployment (since the increase in the participation of women makes the labor market more tight for the potential workers). The shock would reduce the deficits of the public sector pension system (4.5% of GDP in 2050 against 5.3% in the base scenario), but it would be not sufficient to make the system sustainable. The results of this sensitivity analysis are available from the authors upon request.

less than 55. The proposed reform is thus implemented between 2025 and 2045. The shocks, introduced in 2025, are considered to be unanticipated.

As shown in table 9, the main macroeconomic effects are the increase in investments over the entire period and the significant fall in the tax rate. These two effects are explained by the reduction in the deficits of the public sector pension scheme obtained through the implementation of the proposed reform, as shown below. In addition, the raise of the capital stock implies an increase in the capital per unit of effective labor and, thus, a decrease in the interest rate.

Concerning the labor market, the increase in the contribution rate and the reduction in the level of pensions make the public sector less attractive, while the lower income tax rate makes the private sector more attractive compared to the informal sector. As shown in table 10, the decrease in the share of individuals who choose to work in the public sector is offset by the increase in the share of individuals who choose to work in the private sector, while the size of the informal sector, in terms of number of workers, remains essentially unchanged with respect to the base scenario. The shock also produces a significant reduction in the unemployment rate, which is mainly explained by the fall in the interest rate (which induces firms to create more vacancies) and by the fall in the wages negotiated by the private sector workers (since they experience a fall in the tax rate).

Concerning the public sector pension system, as shown in table 11, the proposed reform guarantees its sustainability since the pension system would generate very low deficits compared to the base scenario. Indeed, the proposed reform would make it possible to increase contributions (through the increase in the contribution rate) and to keep pension expenditures under control (by reducing the replacement rate, by reducing the number of survivor's pensions and by eliminating early retirement). The analysis of each policy separately shows that the most effective policy in reducing deficits is the increase in the contribution rate until 2035 and, thereafter, the reduction in the replacement rate.

5.2.2 Reform of the private sector pension scheme

The simulation results of our base scenario show that the private sector pension scheme is sustainable. However, as mentioned before, the ratio between the average pension and the average salary is very low, which implies that the standards of living of people aged 65 and over is very low compared to that of working-age people. One solution that would improve the living conditions of the retirees is to increase the contribution rate in the private sector pension scheme. This is why, in the following simulations, we double the contribution rate (from 8.5% to 17%) starting from 2025. In the first scenario ($c2\_A$), contributions are paid only by the employers as in the current system (i.e. $\tau^{f}_{c2,t} = 17\%$) while, in the second scenario ($c2\_B$), contributions are paid by the employers and by the employees in the same proportion (i.e. $\tau^{f}_{c,t} = 8.5\%$ and $\tau^{w}_{c,t} = 8.5\%$). Thus, the increase in the contribution rate is paid by the firms in the first case and by the employees in the second case.

The results of these two scenarios are shown in tables 12, 13 and 14. First, the two scenarios induce a rise the unemployment rate with respect to the base scenario. In particular, in scenario $c2\_A$, the increase in the contribution rate paid by the employers implies an increase in the labor cost that reduces the incentive for firms to post vacancies. In scenario $c2\_B$, given that private employees pay contributions, they ask for a higher salary which, again, reduces the incentive for firms to create vacancies. Thus, in both cases, the effect is an increase in unemployment. Interestingly, the effect is greater in the second case, implying that the disincentive to post vacancies is greater in the case where employees ask for a higher wage. Concerning the choice of the sector of activity, the share of individuals who choose to work in the private sector slightly decreases. This is explained by the fact that the reduction in the net wage in the private sector (because firms negotiate a lower wage in scenario $c2\_A$ and because of the increase in the contribution rate in scenario $c2\_B$) more than compensates the future increase in the end-of-service indemnity.

The other macroeconomic effects are quite small. Both reforms slightly reduce employment (due to the rise in the unemployment rate) and slightly increase the capital stock (as the investment-to-GDP ratio increases), leaving the economic growth essentially unchanged.

Concerning the effects on the financial situation of the private sector pension scheme, the proposed reform would significantly increase the size of the private sector pension scheme compared to the base scenario. In particular, the two reforms significantly increase contributions (in scenario $c2\_A$, 3.8% of GDP in 2050 and, in scenario $c2\_B$, 4.1% of GDP in 2050, compared to 2.1% of GDP in 2050 in the base scenario) and pension expenditures (in scenario $c2\_A$, 3.1% of GDP in 2050 and 4.1% in 2060 and, in scenario $c2\_B$, 3.3% of GDP in 2050 and 4.4% in 2060, compared to 2.1% in 2050 and 2.5% in 2060 in the base scenario). Note that the magnitude of these two effects is higher in scenario $c2\_B$ because this shock induces the private sector workers (who now have to pay contributions) to negotiate higher wages, which involves higher amounts of contributions and pensions at the aggregate level. In both simulations, the surplus of the private sector pension system (computed by including the interest on the pension fund) is greater than that obtained in the base scenario. However, it is worth noting that the positive effect on the pension surplus is expected to disappear in the long run. Indeed, for people who retire starting from 2065, the end-of-service indemnity is computed exclusively on the basis of the higher contribution rate,[20] which implies that the positive effect (because of higher contributions) will be completely offset by the negative effect (because of higher pension benefits). Finally, the simulation results also show that, compared to the base scenario, the two proposed reforms would improve the economic situation of the elderly. Indeed, the ratio between the average pension and the average salary would be 24.9% in 2060 in the scenarios $c2\_A$ and 25.2% $c2\_B$ against 20.3% in the base scenario.

[20] This is not the case for people who retire between 2030 and 2060 since the contributions paid during their working life are computed on the basis of the old contribution rate until 2020 and of the new one starting from 2025.

In the last scenario, noted $c2\_C$, we evaluate the effects of (i) the transformation of the end-of-service indemnity into an annuity payment and (ii) the transition from the current funded system toward a PAYG system. In particular, we consider the introduction of a Notional Defined Contribution system (NDC, hereafter) which is a PAYG system where pensions are computed according to actuarial principles.[21] We also assume that early retirement is not allowed and that pensions are indexed on inflation (implying that, for the same individual, pensions remain constant over time). The pension for a private sector employee who retires at age 65 is computed according to actuarial principles, i.e. such that the discounted present value of all pensions (weighted by the survival probabilities) is equal to the capitalized value of all the contributions paid:

$$pens_{11,s,e,c2,t} = \frac{\sum_{g=1}^{10} \tau^{f}_{c2,t+g-11} \cdot w_{e,c2,t+g-11} \cdot A_{g,s,e,c2,t+g-11} \cdot \left(1+r^{NDC}\right)^{11-g}}{\sum_{g=11}^{18} \frac{\beta_{g,s,t+g-11}}{\beta_{11,s,t}} \cdot \left(1+r^{NDC}\right)^{11-g}} \quad (51)$$

where the contribution rate (assumed to be paid only by the employers, as in simulation $c2\_A$) is fixed at 17% and the notional interest rate, noted r^{NDC}, is fixed at 6% per year. Note that the notional interest rate, and consequently the implicit rate of return on contributions, is higher than the wage bill growth rate (since the annual productivity growth rate is assumed to be 1.5%) which implies the violation of the Aaron-Samuelson condition. Nonetheless, we find that the private sector system remains sustainable. In fact, while the transition from a PAYG system to a fully-funded system is very costly for the economy (since current workers have to pay contributions twice, once for themselves and once for the current retirees), the transition from a fully-funded system to a PAYG system produces the opposite effect. In this latter case, additional resources become available since current pensions can be financed by current contributions and also by past contributions, i.e. the available pension reserves. Thus, it would be possible to use pension reserves

[21] See Valdès-Prieto (2000) for a review of NDC systems.

to finance pensions without paying contributions for several years or, as we assume here, to compute pensions on the basis of a high implicit rate of return on contributions.

Concerning the effects of this reform, given that pensions are paid according to the new method starting from 2025 (which means that people aged 65 receive an annualized pension instead of the end-of-service indemnity), pension expenditures would be significantly lower than in 2025 (0.4% of GDP against 1.1% in the base scenario) and the private sector regime consequently would produce a higher surplus. In addition, starting from 2025, the size of pension reserves, and consequently the level of public debt, would be higher than in the base scenario, which implies that the tax rate would be significantly lower compared to that of the base scenario and scenario $c2\_A$. In addition, compared to the base scenario and scenario $c2\_A$, there is an increase in the share of individuals who choose to work in the private sector. Indeed, although firms negotiate a lower wage to compensate for the increase in contributions (as in scenario $c2\_A$), scenario $c2\_C$ implies a significant gain in terms of pensions[22] that makes the private sector more attractive.

The macroeconomic effects of the shock are quite small. As in the case of scenario $c2\_A$, we observe an increase in investments and a decrease in the tax rate until 2040. Concerning the financial situation of the private sector pension scheme, it is important to note that in scenario $c2\_C$ the transition from the funded system to the PAYG system by notional accounts will be completed in 2065, i.e. 40 years after the introduction of the reform where all individuals aged 65 and over will obtain an annualized pension. In 2060, i.e. when the transition is not entirely completed, pension expenditures would represent 4.8% of GDP, which is higher compared to the base scenario and also to scenarios $c2\_A$ and $c2\_B$ since the notional interest rate used in scenario $c2\_C$ is higher than the rate of return used to compute the end-of-service indemnity in scenarios $c2\_A$ and $c2\_B$.

[22] This is explained by the fact that, in scenario $c2\_A$, the end-of-service indemnity is computed by capitalizing past contributions on the basis of the rate of return $\tilde{r}_t$ (which, in the numerical simulations, is between 3% and 4%), whereas, in scenario $c2\_C$, the annual pension is computed by capitalizing past contributions on the basis of the notional interest rate of 6%.

Finally, the proposed reform, by raising the size of the private sector pension scheme, would make it possible to increase the ratio between the average pension and the average salary (30.5% in 2060 against 20.3% in the base scenario), which would imply a significant improvement in the standard of living of the elderly compared to working-age individuals. However, it should also be noted that the ratio between the average pension and the average salary remains quite low. This problem is clearly explained by the fact that a large part of the population is not covered by any social security system. This implies the need to implement appropriate public policies aimed at reducing the size of the informal sector and at increasing the labor participation, especially for women.

6. Conclusion

This article evaluates the effects of population ageing in Lebanon which, as most developing countries, is characterized by a low participation of women in the labor market, a large size of the informal sector and a high unemployment rate, in particular for young highly educated people. The analysis of the economic consequences at the macro level and on the sustainability of the pension system is carried out using an OLG model with search and matching frictions by extending the model proposed by de la Croix et al. (2013).

Our simulations show that the public sector pension scheme is highly unsustainable. This is mainly due to the low level of the contribution rate considering the high replacement rate, the extremely generous survivor's pensions, and the very common early retirement. In contrast, the private sector pension scheme, which is a funded system that pays a unique lump-sum transfer when people retire, is sustainable. However, the size of the private sector pension scheme is very small. Besides the low labor participation and the large informal sector, the small size of the private sector pension scheme explains the high level of extreme poverty among people aged 65 and over.

It is important to note that, contrary to developed countries where the pension sustainability can only be achieved by implementing standard policies (such as increasing the retirement age, increasing the contribution rate, or reducing the pension benefits), developing countries have additional available tools. In fact, they can face the pension sustainability problem and improve the conditions of the elderly by introducing incentives for women to participate in the labor market and for informal workers to become formal.

Finally, concerning the problem of the structural mismatch between labor demand and labor supply that characterizes the labor market in Lebanon and in other developing countries as well, the government should promote policies aiming at (i) improving the adequacy of the education system's outcomes and the labor market needs, and (ii) subsidizing firms which are able to create high skilled jobs in order to absorb the exceeding high educated labor force.

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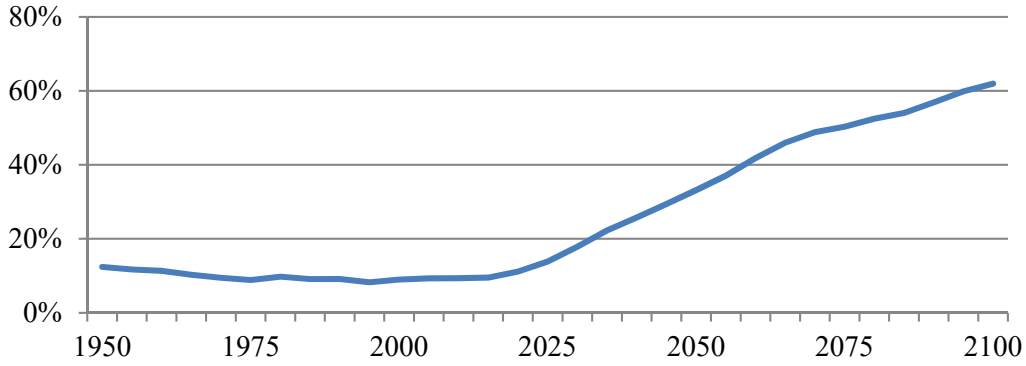
Table 1: Lebanese demographic evolution

	Total population	Children per woman	Life expectancy at birth		0-14 / Total pop.	15-64 / Total pop.	65+ / Total pop.
			Women	Men			
1950	1 335	5.74	62.2	58.9	34.2%	58.5%	7.3%
1975	2 576	4.23	69.4	65.9	39.8%	55.3%	4.9%
2000	3 843	2.20	77.4	73.9	31.1%	63.2%	5.7%
2005	4 699	1.90	79.7	76.0	30.3%	63.7%	5.9%
2010	4 953	2.08	80.6	76.9	25.8%	67.8%	6.4%
2015	6 533	2.09	80.8	77.0	27.3%	66.3%	6.3%
2020	6 825	2.02	81.2	77.5	25.1%	67.4%	7.5%
2025	6 397	1.96	81.8	78.4	22.8%	67.8%	9.4%
2050	6 528	1.77	85.2	83.0	16.1%	63.0%	20.9%
2075	6 358	1.74	88.0	85.9	14.3%	57.0%	28.7%
2100	5 707	1.74	90.3	88.0	13.7%	53.3%	33.1%

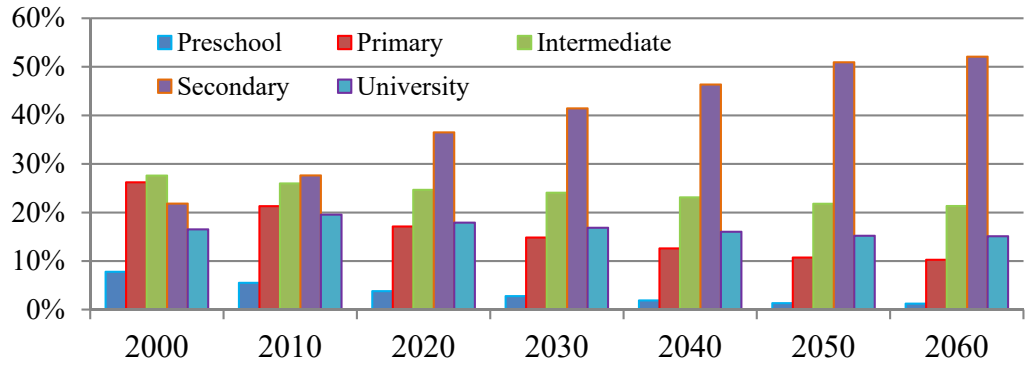
Source: World Population Prospects: 2019 Revision.

Figure 1: Old-age dependency ratio (65+ / 15-64)



Source: World Population Prospects: 2019 Revision.

Figure 2: Composition of the population by education level



Source: Authors calculations using data from CAS and ILO.

Table 2: Main parameters used in the calibration of the OLG model

α	Exponent in the CD production function	0.20
σ	Elasticity of substitution between units of effective labor	3
δ	Annual depreciation rate	3.0%
g	Annual productivity growth rate	1.5%
ρ	Rate of time preference	0.18
π^R	Annual spread	3.1%

			Preschool	Primary	Intermediate	Secondary	University
χ	Separation rate	Public sector	-	-	-	0%	0%
		Private sector	60%	60%	60%	40%	40%
		Informal sector	60%	60%	60%	40%	40%
α_search	Constant in the matching functions	Public sector	-	-	-	0.666	0.663
		Private sector	0.784	0.734	0.688	0.643	0.640
		Informal sector	0.853	0.802	0.751	0.710	0.707
β_search	Exponent in the matching functions	Public sector	-	-	-	0.5	0.5
		Private sector	0.5	0.5	0.5	0.5	0.5
		Informal sector	0.5	0.5	0.5	0.5	0.5
η	Negotiation power of workers	Public sector	-	-	-	0.5	0.5
		Private sector	0.5	0.5	0.5	0.5	0.5
		Informal sector	0.5	0.5	0.5	0.5	0.5

Table 3a: Comparison of data and model results for year 2010 – Macro data

		Model	Data
GDP (billions of Lebanese pounds)		57.954	57.954
Investment / GDP		20.0%	20.0%
Labor participation rate	Total	49.1%	47.6%
	Women	22.8%	22.8%
	Men	72.8%	72.8%
	Preschool	27.0%	22.1%
	Primary	59.0%	53.8%
	Intermediate	56.4%	50.0%
	Secondary	45.8%	39.2%
	University	39.4%	58.0%
Unemployment rate	Total	6.3%	6.4%
	Women	7.4%	10.4%
	Men	6.0%	5.0%
	Preschool	4.4%	4.4%
	Primary	4.6%	4.6%
	Intermediate	5.2%	5.2%
	Secondary	7.7%	7.7%
	University	8.8%	8.8%
Total wages in the public sector / GDP		6.7%	6.7%

Table 3b: Comparison of data and model results for year 2010 – Public sector pension scheme

			Model	Data
Pension expenditures / GDP			3.1%	3.1%
Pension contributions / GDP			0.4%	0.4%
Number of contributors (in thousands)	Men and women		163.132	162.659
	Women		33.697	33.492
	Men		129.434	129.167
Number of retirees (in thousands)	Men and women	All	78.224	78.235
		Less than 65	47.048	47.059
		65 and over	31.176	31.176
	Women	Less than 65	20.077	20.077
		65 and over	10.496	10.496
	Men	Less than 65	26.972	26.982
		65 and over	20.680	20.680

Table 3c: Comparison of data and model results for year 2010 – Private sector pension scheme

			Model	Data
Pension expenditures / GDP			0.5%	0.5%
Pension contributions / GDP			2.2%	2.2%
Number of contributors (in thousands)	Men and women		549.774	546.952
	Women		209.392	209.478
	Men		340.382	337.474
Number of retirees (in thousands)	Men and women	All	15.522	15.522
		Less than 65	12.500	12.500
		65 and over	3.022	3.022

Table 4: Base scenario – Macroeconomic results

	2010	2020	2030	2040	2050	2060
Capital per unit of effective labor	0.326	0.376	0.478	0.543	0.589	0.654
Annual interest rate	7.1%	6.0%	4.6%	4.1%	3.9%	3.3%
Tax rate	19.8%	20.1%	24.1%	26.4%	28.1%	30.3%
Investments / GDP	20.0%	18.7%	16.7%	13.3%	11.5%	9.4%
Annual GDP growth rate	5.5%	4.2%	1.7%	2.3%	2.0%	1.3%
Annual GDP per person growth rate	3.1%	2.6%	1.9%	1.4%	1.6%	1.2%

Table 5: Base scenario – Results on the labor market (labor participation)

			2010	2020	2030	2040	2050	2060
Labor participation rate		Women	22.8%	24.4%	24.4%	23.9%	24.0%	24.1%
		Men	72.8%	76.3%	77.6%	77.7%	77.6%	78.3%
		Total	49.1%	51.3%	51.9%	51.6%	51.9%	52.8%
Choice of the sector of activity	Preschool	Private sector	38.3%	41.9%	37.3%	38.6%	37.9%	35.9%
		Informal sector	61.7%	58.1%	62.7%	61.4%	62.1%	64.1%
	Primary	Private sector	29.5%	31.9%	31.1%	30.5%	30.8%	29.8%
		Informal sector	70.5%	68.1%	68.9%	69.5%	69.2%	70.2%
	Intermediate	Private sector	37.0%	36.2%	35.4%	35.8%	35.0%	34.4%
		Informal sector	63.0%	63.8%	64.6%	64.2%	65.0%	65.6%
	Secondary	Public sector	32.8%	33.3%	31.0%	32.0%	29.9%	29.3%
		Private sector	30.1%	28.6%	26.3%	24.8%	24.8%	24.4%
		Informal sector	37.1%	38.1%	42.7%	43.2%	45.3%	46.3%
	University	Public sector	14.8%	14.9%	14.6%	15.7%	18.3%	17.4%
		Private sector	56.1%	57.2%	51.8%	47.6%	43.9%	43.1%
		Informal sector	29.1%	27.9%	33.6%	36.7%	37.8%	39.5%
	Total	Public sector	11.3%	9.9%	10.2%	11.6%	11.8%	11.5%
		Private sector	36.6%	36.5%	35.0%	34.1%	33.7%	32.9%
		Informal sector	52.0%	53.5%	54.7%	54.3%	54.5%	55.6%

Table 6: Base scenario – Results on the labor market (productivity and wages)

			2010	2020	2030	2040	2050	2060
Marginal productivity of labor *(normalized to 1 in 2010)*		Public sector	1.000	1.057	1.094	1.069	1.075	1.103
		Private sector	1.000	1.025	1.089	1.130	1.157	1.190
		Informal sector	1.000	1.028	1.071	1.099	1.115	1.132
Wage per unit of effective labor *(normalized to 1 in 2010)*	Public sector	Secondary	1.000	1.000	1.000	1.000	1.000	1.000
		University	1.000	1.000	1.000	1.000	1.000	1.000
	Private sector	Preschool	1.000	0.990	1.023	1.019	1.110	1.087
		Primary	1.000	1.016	1.032	1.061	1.084	1.132
		Intermediate	1.000	1.015	1.030	1.037	1.075	1.080
		Secondary	1.000	1.014	1.033	1.069	1.105	1.129
		University	1.000	1.008	1.042	1.077	1.135	1.149
	Informal sector	Preschool	1.000	1.008	1.039	1.058	1.088	1.101
		Primary	1.000	1.010	1.036	1.057	1.079	1.104
		Intermediate	1.000	1.010	1.034	1.052	1.075	1.092
		Secondary	1.000	1.011	1.039	1.072	1.090	1.104
		University	1.000	1.007	1.040	1.062	1.089	1.104

Table 7: Base scenario – Results on the labor market (unemployment and informality)

		2010	2020	2030	2040	2050	2060
Employment rate		46.0%	48.7%	50.8%	51.0%	51.5%	52.5%
Unemployment rate	Women	7.4%	5.4%	2.4%	1.6%	1.1%	0.8%
	Men	6.0%	4.9%	2.1%	1.3%	0.7%	0.5%
	Preschool	4.4%	4.8%	2.8%	2.3%	1.0%	1.7%
	Primary	4.6%	5.1%	1.7%	0.9%	0.5%	0.2%
	Intermediate	5.2%	2.6%	1.0%	0.0%	0.0%	0.0%
	Secondary	7.7%	6.1%	2.2%	2.3%	1.6%	1.3%
	University	8.8%	6.9%	4.3%	2.1%	1.0%	0.8%
	Total	6.3%	5.0%	2.2%	1.3%	0.8%	0.6%
Informality	Informal workers / Total workers	52.6%	53.8%	54.9%	54.8%	55.0%	55.9%
	Informal wages / GDP	40.3%	40.8%	41.5%	41.3%	41.3%	41.9%

Table 8: Base scenario – Results on the pension schemes

		2010	2020	2030	2040	2050	2060
Public sector	Retired / Workers	0.480	0.549	0.877	0.988	1.231	1.444
	Pensions / GDP	3.1%	2.6%	3.9%	4.8%	5.7%	6.3%
	Contributions / GDP	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%
	Surplus / GDP	-2.7%	-2.2%	-3.5%	-4.4%	-5.3%	-5.9%
Private sector	Retired / Workers	0.028	0.040	0.080	0.127	0.165	0.203
	Pensions / GDP	0.5%	0.9%	1.5%	1.9%	2.1%	2.5%
	Contributions / GDP	2.2%	2.2%	2.2%	2.1%	2.1%	2.0%
	Surplus / GDP	2.7%	2.8%	2.8%	3.1%	3.4%	3.2%
	Reserves / GDP	26.8%	36.1%	56.1%	72.9%	90.1%	110.6%
Average pension / Average salary		24.5%	20.0%	21.7%	22.2%	21.9%	20.3%

Table 9: Reform of the public sector pension scheme – Macroeconomic effects

		2025	2030	2035	2040	2050	2060
Capital per unit of effective labor	Base scenario	0.423	0.478	0.514	0.543	0.589	0.654
	Reform	0.419	0.477	0.516	0.548	0.597	0.664
Annual interest rate	Base scenario	5.3%	4.6%	4.4%	4.1%	3.9%	3.3%
	Reform	5.3%	4.6%	4.4%	4.0%	3.8%	3.2%
Tax rate	Base scenario	21.6%	24.1%	24.7%	26.4%	28.1%	30.3%
	Reform	18.7%	19.7%	19.4%	20.4%	22.0%	24.5%
Investment / GDP	Base scenario	18.5%	16.7%	14.9%	13.3%	11.5%	9.4%
	Reform	19.2%	17.5%	15.6%	13.8%	11.8%	9.4%
Annual growth rate of GDP	Base scenario	2.0%	1.7%	2.1%	2.3%	2.0%	1.3%
	Reform	2.1%	1.8%	2.2%	2.3%	2.0%	1.3%
Annual growth rate of GDP per person	Base scenario	2.7%	1.9%	1.7%	1.4%	1.6%	1.2%
	Reform	2.8%	2.0%	1.8%	1.4%	1.6%	1.2%

Table 10: Reform of the public sector pension scheme – Effects on the labor market

			2025	2030	2035	2040	2050	2060
Choice of the sector of activity	Public sector	Base scenario	9.9%	10.2%	11.2%	11.6%	11.8%	11.5%
		Reform	8.2%	8.6%	9.4%	9.9%	10.0%	9.6%
	Private sector	Base scenario	35.8%	35.0%	34.5%	34.1%	33.7%	32.9%
		Reform	36.8%	36.2%	35.8%	35.5%	35.1%	34.4%
	Informal sector	Base scenario	54.4%	54.7%	54.4%	54.3%	54.5%	55.6%
		Reform	55.0%	55.2%	54.8%	54.6%	54.8%	56.0%
Unemployment rate	Total	Base scenario	3.2%	2.2%	1.8%	1.3%	0.8%	0.6%
		Reform	2.6%	1.8%	1.1%	0.8%	0.2%	0.2%
	Women	Base scenario	3.3%	2.4%	2.0%	1.6%	1.1%	0.8%
		Reform	2.6%	1.9%	1.0%	0.8%	0.1%	0.1%
	Men	Base scenario	3.1%	2.1%	1.7%	1.3%	0.7%	0.5%
		Reform	2.6%	1.7%	1.1%	0.8%	0.2%	0.2%
Informality		Base scenario	54.5%	54.9%	54.8%	54.8%	55.0%	55.9%
		Reform	54.7%	55.1%	54.9%	54.8%	54.9%	56.1%

Table 11: Reform of the public sector pension scheme – Effects on the pension system

		2025	2030	2035	2040	2050	2060
Pension expenditures / GDP	Base scenario	2.9%	3.9%	4.0%	4.8%	5.7%	6.3%
	Shock on the contribution rate	2.9%	3.9%	4.0%	4.8%	5.5%	6.1%
	Shock on the replacement rate	2.7%	3.3%	3.1%	3.3%	3.2%	3.1%
	Shock on early retirement	2.7%	3.0%	3.0%	3.9%	5.7%	6.8%
	Shock on survivor's pensions	2.5%	3.2%	3.2%	3.8%	4.8%	5.9%
	Entire reform	2.1%	2.1%	1.8%	2.1%	2.7%	3.4%
Pension contributions / GDP	Base scenario	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%
	Shock on the contribution rate	1.3%	1.3%	1.4%	1.4%	1.5%	1.4%
	Shock on the replacement rate	0.3%	0.3%	0.4%	0.4%	0.4%	0.4%
	Shock on early retirement	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%
	Shock on survivor's pensions	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%
	Entire reform	1.3%	1.3%	1.4%	1.4%	1.4%	1.4%
Pension surplus / GDP	Base scenario	-2.6%	-3.5%	-3.7%	-4.4%	-5.3%	-5.9%
	Shock on the contribution rate	-1.6%	-2.6%	-2.6%	-3.3%	-4.0%	-4.6%
	Shock on the replacement rate	-2.4%	-2.9%	-2.7%	-2.9%	-2.8%	-2.7%
	Shock on early retirement	-2.3%	-2.7%	-2.6%	-3.5%	-5.3%	-6.4%
	Shock on survivor's pensions	-2.2%	-2.9%	-2.8%	-3.4%	-4.4%	-5.5%
	Entire reform	-0.9%	-0.8%	-0.4%	-0.6%	-1.3%	-2.0%

Table 12: Reform of the private sector pension scheme – Macroeconomic effects

		2025	2030	2035	2040	2050	2060
Capital per unit of effective labor	Base scenario	0.423	0.478	0.514	0.543	0.589	0.654
	Scenario *c2_A*	0.425	0.481	0.519	0.548	0.593	0.657
	Scenario *c2_B*	0.427	0.481	0.518	0.546	0.587	0.649
	Scenario *c2_C*	0.422	0.487	0.528	0.566	0.627	0.698
Annual interest rate	Base scenario	5.3%	4.6%	4.4%	4.1%	3.9%	3.3%
	Scenario *c2_A*	5.3%	4.5%	4.3%	4.0%	3.8%	3.2%
	Scenario *c2_B*	5.3%	4.5%	4.3%	4.0%	3.8%	3.3%
	Scenario *c2_C*	5.2%	4.4%	4.1%	3.6%	3.2%	2.7%
Investment / GDP	Base scenario	18.5%	16.7%	14.9%	13.3%	11.5%	9.4%
	Scenario *c2_A*	18.8%	17.1%	15.3%	13.8%	12.2%	10.3%
	Scenario *c2_B*	18.6%	16.8%	15.0%	13.4%	11.7%	9.8%
	Scenario *c2_C*	20.0%	18.4%	17.2%	16.2%	15.2%	13.4%
Tax rate	Base scenario	21.6%	24.1%	24.7%	26.4%	28.1%	30.3%
	Scenario *c2_A*	18.8%	21.7%	22.6%	24.7%	27.3%	30.5%
	Scenario *c2_B*	17.5%	20.4%	21.4%	23.6%	26.2%	29.6%
	Scenario *c2_C*	17.8%	21.0%	22.3%	24.8%	28.6%	34.3%
Annual growth rate of GDP	Base scenario	2.0%	1.7%	2.1%	2.3%	2.0%	1.3%
	Scenario *c2_A*	2.0%	1.8%	2.2%	2.3%	2.0%	1.3%
	Scenario *c2_B*	2.0%	1.8%	2.1%	2.2%	2.0%	1.2%
	Scenario *c2_C*	1.9%	1.7%	2.2%	2.3%	1.9%	1.1%
Annual growth rate of GDP per person	Base scenario	2.7%	1.9%	1.7%	1.4%	1.6%	1.2%
	Scenario *c2_A*	2.7%	2.0%	1.7%	1.4%	1.6%	1.2%
	Scenario *c2_B*	2.7%	1.9%	1.7%	1.4%	1.6%	1.2%
	Scenario *c2_C*	2.6%	1.9%	1.8%	1.4%	1.5%	1.1%

Scenario *c2_A:* Fully funded system with $\tau_{c2}^{f} = 17\%$.
Scenario *c2_B*: Fully funded system with $\tau_{c2}^{f} = 8.5\%$ and $\tau_{c2}^{w} = 8.5\%$.
Scenario *c2_C*: NDC system with $\tau_{c2}^{f} = 17\%$.

Table 13: Reform of the private sector pension scheme – Effects on the labor market

			2025	2030	2035	2040	2050	2060
Choice of the sector of activity	Public sector	Base scenario	9.9%	10.2%	11.2%	11.6%	11.8%	11.5%
		Scenario *c2_A*	10.2%	10.5%	11.4%	11.8%	11.9%	11.5%
		Scenario *c2_B*	10.3%	10.6%	11.5%	11.9%	12.0%	11.6%
		Scenario *c2_C*	10.1%	10.4%	11.3%	11.6%	11.5%	11.0%
	Private sector	Base scenario	35.8%	35.0%	34.5%	34.1%	33.7%	32.9%
		Scenario *c2_A*	35.2%	34.5%	33.9%	33.5%	33.0%	32.1%
		Scenario *c2_B*	35.0%	34.2%	33.7%	33.2%	32.6%	31.7%
		Scenario *c2_C*	35.5%	34.7%	34.1%	33.7%	33.2%	32.0%
	Informal sector	Base scenario	54.4%	54.7%	54.4%	54.3%	54.5%	55.6%
		Scenario *c2_A*	54.6%	55.0%	54.7%	54.7%	55.1%	56.4%
		Scenario *c2_B*	54.7%	55.1%	54.9%	54.9%	55.4%	56.7%
		Scenario *c2_C*	54.4%	54.9%	54.6%	54.7%	55.2%	57.0%
Unemployment rate	Women	Base scenario	3.3%	2.4%	2.0%	1.6%	1.1%	0.8%
		Scenario *c2_A*	3.9%	2.6%	2.1%	1.7%	0.7%	0.2%
		Scenario *c2_B*	4.2%	2.8%	2.3%	1.8%	0.8%	0.3%
		Scenario *c2_C*	2.7%	2.2%	0.7%	0.6%	0.2%	0.2%
	Men	Base scenario	3.1%	2.1%	1.7%	1.3%	0.7%	0.5%
		Scenario *c2_A*	3.5%	2.2%	1.8%	1.2%	0.5%	0.3%
		Scenario *c2_B*	3.7%	2.3%	1.9%	1.4%	0.5%	0.3%
		Scenario *c2_C*	2.8%	1.9%	1.0%	0.7%	0.3%	0.2%
	Total	Base scenario	3.2%	2.2%	1.8%	1.3%	0.8%	0.6%
		Scenario *c2_A*	3.6%	2.3%	1.8%	1.3%	0.5%	0.3%
		Scenario *c2_B*	3.8%	2.4%	2.0%	1.5%	0.6%	0.3%
		Scenario *c2_C*	2.8%	2.0%	0.9%	0.6%	0.3%	0.2%
Informality		Base scenario	54.5%	54.9%	54.8%	54.8%	55.0%	55.9%
		Scenario *c2_A*	54.9%	55.2%	55.2%	55.2%	55.4%	56.6%
		Scenario *c2_B*	55.1%	55.4%	55.4%	55.4%	55.7%	56.9%
		Scenario *c2_C*	54.3%	55.0%	54.7%	54.9%	55.4%	57.1%

Scenario *c2_A:* Fully funded system with $\tau_{c2}^{f} = 17\%$.
Scenario *c2_B*: Fully funded system with $\tau_{c2}^{f} = 8.5\%$ and $\tau_{c2}^{w} = 8.5\%$.
Scenario *c2_C*: NDC system with $\tau_{c2}^{f} = 17\%$.

Table 14: Reform of the private sector pension scheme – Results on the pension system

		2025	2030	2035	2040	2050	2060
Pension expenditures / GDP	Base scenario	1.1%	1.5%	1.7%	1.9%	2.1%	2.5%
	Scenario *c2_A*	1.1%	1.7%	2.0%	2.4%	3.1%	4.1%
	Scenario *c2_B*	1.1%	1.7%	2.0%	2.5%	3.3%	4.4%
	Scenario *c2_C*	0.4%	0.9%	1.4%	2.0%	3.0%	4.8%
Pension contributions / GDP	Base scenario	2.2%	2.2%	2.1%	2.1%	2.1%	2.0%
	Scenario *c2_A*	4.0%	4.0%	3.9%	3.9%	3.8%	3.7%
	Scenario *c2_B*	4.3%	4.3%	4.2%	4.1%	4.1%	4.0%
	Scenario *c2_C*	4.0%	3.9%	3.8%	3.8%	3.7%	3.4%
Pension surplus / GDP	Base scenario	2.9%	2.8%	3.2%	3.1%	3.4%	3.2%
	Scenario *c2_A*	4.7%	4.8%	5.4%	5.3%	5.6%	5.0%
	Scenario *c2_B*	5.0%	5.1%	5.7%	5.7%	6.0%	5.4%
	Scenario *c2_C*	5.4%	5.5%	5.9%	5.6%	5.0%	3.1%
Pension reserves / GDP	Base scenario	45.8%	56.1%	64.0%	72.9%	90.1%	110.6%
	Scenario *c2_A*	45.8%	64.3%	80.4%	97.4%	130.0%	165.2%
	Scenario *c2_B*	45.8%	65.7%	83.1%	101.6%	136.9%	175.1%
	Scenario *c2_C*	45.8%	67.3%	85.6%	104.1%	136.6%	164.8%
Average pension / Average salary	Base scenario	21.0%	21.7%	20.9%	22.2%	21.9%	20.3%
	Scenario *c2_A*	21.6%	22.8%	22.5%	24.5%	25.2%	24.9%
	Scenario *c2_B*	21.1%	22.4%	22.2%	24.3%	25.2%	25.2%
	Scenario *c2_C*	18.5%	20.9%	22.7%	25.6%	28.4%	30.5%

Scenario *c2_A:* Fully funded system with $\tau_{c2}^{f} = 17\%$.
Scenario *c2_B*: Fully funded system with $\tau_{c2}^{f} = 8.5\%$ and $\tau_{c2}^{w} = 8.5\%$.
Scenario *c2_C*: NDC system with $\tau_{c2}^{f} = 17\%$.