Quantifying the effects of social security reform

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Abstract

This paper quantifies the efficiency, inequality and welfare consequences of alternative social security systems. In the context of an overlapping generations model, with ex-ante heterogeneity in productivity, we consider three alternative social security schemes. A funded defined contribution (FDC) system, based on individual capitalization. A notional defined contribution scheme (NDC) with collective capitalization and a non-contributory targeted pension (NTP) scheme, financed with taxes. Our main findings are as follows. First, a collective capitalization system, NDC, reduces pension inequality, without efficiency losses and with overall welfare gains. Second, an FDC scheme, combined with a non-contributory targeted pension, is Pareto efficient: it increases the replacement rate of a low-productivity individual, without reducing the replacement rate of high-productivity workers. However, it implies efficiency and welfare losses as a consequence of distortionary taxes. Third, calibrating for Chile, we find that it is possible to increase the replacement rate of all individuals as well as the aggregate capital in the economy. This is possible with a suitable combination of the three systems previously described.

Keywords: Capital Flows, Demographic Transition, Inequality, Redistribution, Social Security, Welfare.

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Contents

1 Introduction

Pension systems are essential to guarantee social protection in old age. The International Labor Organization, through its recommendation 202, suggests four basic guarantees, including economic security in old age. The objective of the latter is to ensure continuity of income and economic security in the event of retirement or difficulties in obtaining labor income. Barr, Diamond, and Engel (2010) suggest that a pension system can change the standard of living of the elderly and their children, along with potential effects on labor supply and savings. Consequently, the design of the system and its parameters matter.

OECD (2021) defines four types of contributory systems: defined benefit (DB), points systems (PS), funded defined contribution (FDC), and notional defined contribution (NDC) schemes. This paper quantifies the efficiency, inequality and welfare consequences of changing the pension system from FDC to NDC. First, an FDC model is characterized by having individual accounts that invest in the capital market, which are used to pay an annuity at retirement age. Secondly, an NDC scheme with collective capitalization[1] is used. Additionally, a non-contributory pension (NTP) financed by taxes as presented by Heer (2003). It is done with a model of overlapping generations, with ex-ante heterogeneity in the labor market and demographics, perfect foresight, and a closed economy.

The risks faced by the system and what is shared may change depending on the institutional arrangement (Barr, Diamond, and Engel 2010). For example, an FDC system involves accumulating funds until retirement, and then obtaining a pension that can be an annuity or through withdrawals from the fund. In these arrangements, the funds face risks in the stock market. If a person does poorly in the labor market, that risk is expressed in his future pension. Similarly, if a generation does poorly because of a particular economic cycle, that risk is transferred to their pension. In this institutional framework, the labor market risk is not shared; there is no inter- or intra-generational solidarity.

1. This is a special case of NDC, without the pay-as-you-go component and with a collective capitalization fund, where the rate of return is the same as in the assets. A pension agency is established to manage the funds and benefits.

In other mechanisms, such as DB, pensioners receive an amount based on their work history. Workers assume the risks for the return of assets and the generational cohort during their lifetime. When the funds are not invested in the market, as in a pay-as-you-go (PAYG) system, market risk is eliminated, but pensions depend on the income of active workers. In NDC schemes the accounts are "notional", in that the balances exist only on the books of the managing institution. At retirement, the accumulated notional capital is converted into a monthly pension using a formula based on life expectancy (like FDC). Then, depending on the specification of the system, it may be subject to capital market risks (e.g., collective capitalization) or labor market risks (such as PAYG).

Countries are constantly faced with the need to guarantee the coverage, adequacy and sustainability of their pension systems (ILO 2021a). For this purpose, they can make parametric modifications or reforms to the system. For example, Sweden, the Netherlands, Slovak Republic and Brazil have modified the retirement age in recent years. Countries such as Germany, Chile and Mexico have extended basic pensions. Hungary and Poland have adjusted benefits and contributions in earning-related pensions (OECD 2021). In Uruguay, at the time of writing, pension reform is being discussed; similarly, in Chile, where the pension reform debate is ongoing[2].

There is a vast literature documenting the performance, functioning and reforms of pension systems around the world. Recent contributions we can highlight include ILO (2021b) and OECD (2021) for a global overview, and ILO (2021a) and Cepal (2021) for a look at social protection in Latin America and the Caribbean. Similarly, the World Bank, through Andrews et al. (2006), presents a detailed analysis of restructuring pension systems.

Overlapping generations models are widely used to evaluate the macroeconomic and distributive consequences of an economic reform. In this sense, Auerbach and Kotlikoff (1985b) and Auerbach and Kotlikoff (1985a) offer influential evaluation of

2. The Minister of Finance, Mario Marcel, has stated the need to maintain capitalization, but using collective systems. In an interview in May 2022, he stated: "Capitalization is needed to ensure the sustainability of the pension system; it is a necessity for the development of the future system... When we present the reform, we need to decide which form the capitalization will take, collective or individual".

social security reforms while Auerbach and Kotlikoff (1987) does the same for fiscal policy[3]. This literature is useful for evaluating changes in social security. Auerbach and Kotlikoff (1981) examine the effect of social security on savings, with a perfect foresight life-cycle growth model and U.S. data. Auerbach and Kotlikoff (1985a) use a perfect foresight life-cycle simulation to evaluate the demographic change of baby booms and baby busts and their interaction with social security. In particular, the authors use an economy with households, government and production, along with 55 overlapping generations, and evaluate the transition of a change in the social security replacement rate. Auerbach and Kotlikoff (1985a), together with Auerbach and Kotlikoff (1987) which models the dynamics of a tax reform, are important references for my research.

The effect of social security and unemployment compensation, along with welfare analysis, can be found in Hubbard, Skinner, and Zeldes (1995), İmrohoroglu, Imrohoroglu, and Joines (1995), Heer (2003). Attanasio, Kitao, and Violante (2007) develops an Overlapping Generation Model to evaluate demographic trends and social security reforms in a context with two types of economies (advanced and developing). This exercise allows analyzing differences in labor markets, technology, demographics, commodities and assets, while evaluating changes in social security systems. For example, the authors evaluate financing the demographic transition from a pay-as-you-go system by increasing labor taxes, changing the consumption tax, increasing government debt, or reducing the amount of benefit.

Other examples that estimate the consequences of changes in social security systems in developing countries can be found in Song et al. (2015) and Banco Central de Chile (2017). The first case analyzes an intergenerational redistribution with an endogenous labor supply model calibrated for China. In the second case, the authors analyze the macroeconomic effects of a change in the pension system calibrated for Chile.

Following the literature on overlapping generations models, this paper uses a

3. More recent research includes Storesletten (2000), Galaasen (2009) and Amábile and Chumacero (2022), that have written on fiscal policy and demographic changes. Attanasio, Kitao, and Violante (2007) quantify the effect of demographic change in developing countries and Acciari, Polo, and Violante (2022) have assessed intergenerational mobility in Italy.

methodology to evaluate the steady state and transition between different pension systems. An FDC scheme (individual capitalization) will be used as a benchmark in order to evaluate a pension system reform. It will be contrasted with two redistribution mechanisms: i) an NDC system (collective capitalization), and ii) redistribution through taxes.

We will solve a perfect foresight overlapping generations model in a closed economy. An ex-ante heterogeneity in productivity and demographics is introduced. We derive both, the steady state and transition dynamics. A pension agency is introduced that has a balance according to the pension system and population distribution, together with a government that collects taxes on consumption, capital and employment, and can grant transfers to people with low pensions.

Using NDC, can be redistributed through the pension system. Collective capitalization makes it possible to maintain aggregate savings, reduce inequality and improve aggregate welfare. The cost is transferred to high productivity, but the magnitude depends on the populations of high and low productivity. When redistributed through taxes, a target pension is effective in reducing inequality; however, the magnitude and distortions depend on the financing capacity. The wealth tax affects welfare more than taxes on labor and consumption.

The Chilean pension system[4] is an interesting case to study. In 1981 it was changed from DB to a FDC system [5]. In 2006, during Michelle Bachelet's first term as president, a pension advisory commission was formed (Consejo Asesor Presidencial 2006). This created the Basic Solidarity Pension and the Solidarity Pension Contribution to increase low benefits. Subsequently, in Bachelet's second government, a second pension advisory commission was held (Comisión asesora presidencial 2015), which proposed three reform mechanisms; however, no political consensus was reached to implement any of them. Chile currently uses an FDC system with a target pension for lower-income pensions (NTP). It is possible to increase the

4. The Chilean pension system is discussed in Berstein et al. (2006), Barr and Diamond (2016) and Larraín, Ballesteros, and García (2017)

5. This example was very influential in Latin America and other Central and Eastern European countries. However, the results were not as expected, and countries such as Estonia, Latvia, Lithuania, Poland and Romania have reversed part of the changes (Barr and Diamond 2016).

replacement rate of all individuals as well as the aggregate capital in the economy. The replacement rate of low-productivity households can be increased by 42% and the pension gap can be reduced by 19% through an additional 2.5% contribution to the NDC scheme in the Chilean economy, improving the aggregate welfare.

The thesis is organized as follows. Section 2 details the overlapping generations model, along with its components, the agency and pension systems used. Section 3 explains the computation and calibration of the models. The results can be found in section 4, with the details of each pension model and an evaluation of the increase in the contribution rate. Finally, section 5 details the exercise for the Chilean economy.

2 Model

Auerbach and Kotlikoff (1987) presented a framework to study the dynamic nature of fiscal policy and the economy's transition path. The authors used a model with households (55 periods), firms and government to study how a particular reform change the welfare of *different generations*. In the spirit of Auerbach and Kotlikoff (1987), we develop a *stylized 6-generations* model to study the changes in the pension system.

We use an Overlapping Generation Model with perfect foresight. The government announces a change of pension policy, and agents adjust their behavior in time period 1 and all subsequent periods. The economy has four sectors: households, firms, government and pension agency. Workers save for old age and have a ex-ante heterogeneity in productivity and demographics. Firms maximize profits. The government collects taxes and runs a balanced budget. The pension agency collects social security contributions, capitalizes them and pays pensions balancing a budget. The economy is closed, and pension funds are in aggregate capital; in consequence, they affect the national interest rate. The following sections detail households, pension systems, firms, government, and aggregation.

2.1 Households

Agents get utility from standard consumption goods and leisure. The instantaneous utility takes the form $u(c, 1-l)$, where c is current consumption and l labor. Total endowment is normalized to one and allocated to employment and leisure.

$$u(c, 1-l) = \frac{((c+\psi)(1-l)^{\gamma})^{1-\eta} - 1)}{1-\eta} \tag{1}$$

η denotes the coefficient of relative risk aversion, γ is the disutility from working, and ψ is a small constant that guarantees that utility is finite for zero consumption in the case of no income. Households live J periods. The first T periods they work, the last TR they are retired and receive pensions. At t, all agents of age s survive until age $s+1$ with probability ϕ_s. Households maximize lifetime utility at age 1 in period t subject to the intertemporal budget constraints:

$$\max \sum_{s=1}^{J} \beta^{s-1} (\prod_{j=1}^{s} \phi_{t+s-1,s-1}) u(c_{t+s-1}(s), l_{t+s-1}(s)) \tag{2}$$

s.t.

$$c_{t,j}(s)(1+\tau_c) + \omega_{t+1,j}(s+1) = [1+(1-\tau_r)r_t]\omega_{t,j}(s) +$$
$$(1-\tau_w-\tau_{ic}-\tau_{cc})w_t e_j(s) l_{t,j}(s) + P^{ic}_{t,j}(s) + P^{cc}_t(s) + P^{sp}_{t,j}(s) \tag{3}$$

Where β is the discount factor, the term $\prod_{j=1}^{s} \phi_{t+j-1,j-1}$ denotes the unconditional probability of surviving until age s at time t. Households are heterogeneous in their age s, individual labor efficiency $e_j(s)$ and wealth ω. The household's efficiency $e_j(s) = \overline{y}_s \epsilon_j$ depends on its age s, and its efficiency type j (high or low), $\varepsilon \equiv \{\epsilon_1, \epsilon_2\}$. This is an ex-ante heterogeneity; a person is born and remains the same type (high or low). ε captures differences in labor market education or skills.

Agents are born without wealth $\omega_t^1 = 0$, parents cannot leave bequest to their children, and all accidental bequests ($\phi_s \omega_{t,j}(s)$) are confiscated by the government[6]. We introduce proportional taxes on consumption τ_c, wealth τ_r and labor τ_w. Additionally, workers contribute to the individual pension system (τ_{ic}) and collective pension system (τ_{cc}). The net wage income in period t of an *s-year* old household with efficiency type j is $(1-\tau_w-\tau_{ic}-\tau_{cc})w_t e_j(s) l_t(s)$, where w_t is the wage rate per efficiency unit in period t. The retired worker can receive three types of pensions, $P^{ic}_{t,j}(s)$ from individual capitalization, $P^{ic}_t(s)$ from collective capitalization, and $P^{ps}_{t,j}$ from the government budget. The household earns interest r_t on his wealth.

The household's labor supply per generation s and efficiency j:

$$l_{t,j}(s) = 1 - (c_{t,j}(s) + \psi) \left[\frac{(1-\tau_w-\tau_{ic}-\tau_{cc})w_t e_j(s)}{(1+\tau_c)} \right]^{-1} \tag{4}$$

The Euler Equations determine the slope of the household's consumption profile. We obtain:

6. For example, in Krueger and Ludwig (2007), the government collects the deceased households' assets, and redistributes them like a lump-sum transfer.

$$\frac{1}{\beta\phi_t} = \frac{(1+(1-\tau_r)r_t)(c_{t+1,j}(s+1)+\psi)^{-\eta}(1-l_{t+1,j}(s+1))^{\gamma(1-\eta)}}{(c_{t,j}(s)+\psi)^{-\eta}(1-l_{t,j}(s))^{\gamma(1-\eta)}} \tag{5}$$

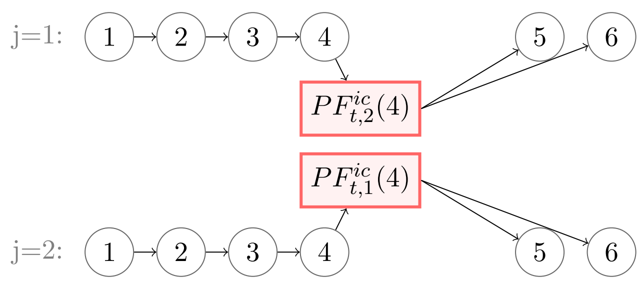
2.2 Pension systems

OECD (2021) defines four types of contributory systems. First, defined benefit (DB) systems, such as pay-as-you-go (PAYG), which according to different specifications are used in 20 OECD countries. Secondly, points schemes (used in 5 countries), where workers obtain points based on their earnings and contributions, and from these points the pension is estimated. Thirdly, there are funded defined contribution (FDC) systems, which operate in 12 countries, and are based on individual accounts to deliver a monthly pension. Finally, there are the notional defined contribution schemes (NDC) in 5 countries; that are PAYG public schemes with individual accounts that apply a notional rate of return to contributions made, similar to FDC systems. Appendix A shows the types of systems and how they can interact in more detail.

This paper focuses on two types of contributory systems. First, an FDC model is developed. The system is characterized by having individual accounts that invest in the capital market, which at retirement age are used to pay an annuity. Therefore, we call this system **individual capitalization**. Secondly, a specific case of notional defined contribution schemes is established. In general, these systems work with individual accounts and interest is credited to the account with a notional rate of return; where retirement is calculated as an annuity, based on life expectancy similar to the FDC system. This paper uses a specific case with no PAYG (no contribution from active workers is used to pay present pensions) and a rate of return equal to assets as in the FDC system. This system is called **collective capitalization**. We develop a pension agency that collects the contributions, capitalizes the funds and finally pays pensions according to a balanced budget.

Different systems share risks differently, "pension systems are subject to multiple sources of risk, and they have different underlying philosophies of who should bear those risks." (Barr, Diamond, and Engel 2010). The heterogeneity in the labor market means we can explore inequity in pensions. The labor market risks are not shared in individual capitalization. If there is a population change or life expectancy increases, the risk does not fall on another generation. Each worker accesses an individual account where funds are accumulated according to a return, at the time of retirement can purchase an annuity or withdraw from the accumulation.

The following figure is a simple representation of the dynamics of individual capitalization pension system in a context of high and low productivity ($j = 1, 2$) with agents who live six periods. In the first four periods, funds are accumulated that earn an interest rate r, until a $PF^{ic}_{t,j}(4)$ pension fund is gathered, then it is distributed over the two withdrawal periods. In this case each individual has a specific background to her productivity.

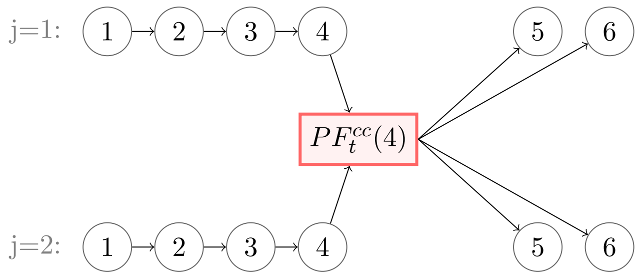


Equation 6 shows the movement of individual funds. A τ_{ic} proportion of income in period t goes to pension funds in $t + 1$, $\pi^{ic}_{t+1,j}(s)$. The fund accumulates at a rate of $1 + r_t$. The heterogeneity of the agents in terms of efficiency and generation determines the accumulated funds.

$$\pi^{ic}_{t+1,j}(s + 1) = (1 + r_t)\pi^{ic}_{t,j}(s) + \tau_{ic} w_t e_j(s) l_{t,j}(s) \tag{6}$$

Fully funded systems differ from traditional defined benefit systems, such as PAYG, in four important ways: i) there are assets or return on funds; ii) labor market risk is not shared in pensions; iii) the risk of pensions comes from the capital market; iv) if the retired population does not buy an annuity, it will faces mortality risks. From these differences, we build a simple model that capitalizes the funds and shares the risks present in the labor market.

The following Figure shows, in a simple way, the operation of collective capitalization. For the first four periods the contribution is accumulated in a collective fund that has a return rate of r, then, the funds are distributed between high and low productivity retirees. In its simplest form we can distribute the funds in equal parts, generating a redistribution similar to a PAYG system. In practice, we will implement a base pension for low-efficiency agents, and then the pension agency will distribute the remaining funds to high-productivity agents. In this method, the population distribution of high and low productivity will be very important.



Equation 7 shows the dynamics of accumulation of the collective fund. A proportion τ_{cc} of the income $w_t(e_1(s)l_{t,1}(s)+e_2(s)l_{t,2}(s))$ goes to the future funds $\pi_{t+1}(s+1)$, and the present funds $\pi_t(s)$ have a return rate of r_t.

$$\pi_{t+1}^{cc}(s+1) = (1+r_t)\pi_t^{cc}(s) + \tau_{cc} w_t(e_1(s)l_{t,1}(s) + e_2(s)l_{t,2}(s)) \tag{7}$$

The pension agency can pay three types of pensions $\{P^{ic}, P^{cc}, P^{ps}\}$, depending on how the worker contributed: individual capitalization (τ_{ic}), collective capitalization (τ_{cc}) or if the agent receives a non-contributory pension financed through general taxes $\{\tau_r, \tau_c, \tau_w\}$.

$$Pension_{t,j}(s) = \begin{cases} 0 & \text{if } s < Retired \\ P_{t,j}^{ic}(s) + P_t^{cc}(s) + P_{t,j}^{sp}(s) & \text{if } s \geq Retired \end{cases} \tag{8}$$

The pension agency aims to have a balanced budget. Income comes from contributions and expenses to pay pensions. In individual capitalization, each balance sheet is separated by efficiency j. For example, in a 6-generation model (work four periods and retire two periods), income is the funds accumulated up to the last year worked ($\pi^{ic}_{t,j}(s)$) multiplied by the number of people with productivity j (μ_j) and age s ($m(4)$), $PF^{ic}_{t,j}(4) = \pi_{t,j}(4)m(4)\mu_j$. The pensions paid are the accumulated funds ($PF^{ic}_{t,j}(4)$) distributed in the retired generations ($m(4)$ and $m(5)$) by the type of productivity (μ_j).

$$P^{ic}_{t,j}(s) = \frac{PF^{ic}_{t,j}(s)}{\mu_j(m(4)+m(5))} \tag{9}$$

In collective capitalization, the pension agency has to distribute the joint budget from the two productivities. Revenues are the funds accumulated by both types of agent, multiplied by generation s and productivity j, $PF^{cc}_t = \pi^{cc}_{t,1}(4)m(4)\mu_1 + \pi^{cc}_{t,2}(4)m(4)\mu_2$. A pension $\hat{P}_t$ is set for low efficiency (j=2). The difference between the income and the pensions paid to the low-efficiency agent ($PF^{cc}_t - \hat{P}_t\mu_2(m(4) + m(5))$) is distributed to pay the high-efficiency pensions ($j = 1$):

$$P^{cc}_{t,j}(s) = \begin{cases} \frac{PF^{cc}_t - (\hat{P}_t\mu_2(m(4)+m(5)))}{\mu_1(m(4)+m(5))} & \text{if } j = 1 \\ \hat{P}_t & \text{if } j = 2 \end{cases} \tag{10}$$

In the case of equal redistribution, it can be established that $P^{cc}_{t,1} = P^{cc}_{t,2}$. Section 4.1 analyzes the effect of increasing the pension obtained by individual capitalization by 50%. As expected, the population and distribution according to productivity will determine the ability to redistribute.

Finally, one option is to finance a non-contributory pension through general taxes as in Heer (2003), in our case with $\{\tau_r, \tau_c, \tau_w\}$. This is a **target pension** (NTP), based on the benefit received from contributory systems (such as the solidarity pension contribution in Chile[7]). In this exercise, all agents pay taxes, the government has a collection and can allocate a transfer (Tr_t) to a specific group (j=2):

7. Aporte Previsional Solidario.

$$P^{sp}_{t,j}(s) = \begin{cases} 0 & \text{if } j = 1 \\ Tr_t & \text{if } j = 2 \end{cases} \tag{11}$$

2.3 Technology

The production technology of the economy is given by a constant returns to scale *Cobb-Douglas* function:

$$Y_t = A_t L_t^{1-\alpha} K_t^{\alpha} \tag{12}$$

where $A > 0$, $\alpha \in (0,1)$ is labor's share of output, and L_t and K_t are aggregate labor and capital inputs, respectively. Productivity A_t grows at the exogenous rate g_A and δ is the depreciation rate. Profit maximization gives rise to the first-order conditions which determine the wage and interest rate:

$$\begin{aligned} r_t &= \alpha L_t^{1-\alpha} K_t^{\alpha-1} - \delta \\ w_t &= (1-\alpha) L_t^{-\alpha} K_t^{\alpha} \end{aligned} \tag{13}$$

2.4 Aggregation

The aggregation of the variables is determined by the population according to generation s and by type of productivity j. Employment and aggregate capital will determine prices in equations 13. The aggregate of individual employment $(l_{t,j}(s))$ of T working generations and two productivities is determined by equation 14. Similarly, consumption C_t is determined for the T periods that the agent works and the TR periods he is retired, where $c_{t,j}(s)$ is the individual consumption of efficiency j and generation s in period t.

$$L_t = \sum_{s=1}^{T} \sum_{j=1}^{2} e_j(s) l_{t,j}(s) m_t(s) \mu_j \tag{14}$$

$$C_t = \sum_{s=1}^{T+TR} \sum_{j=1}^{2} c_{t,j}(s) m(s) \mu_j \tag{15}$$

Aggregate capital is made up of three components: individual savings, individual pension funds, and collective pension funds. Savings is the aggregation by type of productivity j, population $m(s)$ and probability of survival $\phi(s)$, $\Omega_t = \sum_{s=1}^{T+TR} \sum_{j=1}^{2} \omega_{t,j}(s)\phi(s)m(s)\mu_j$. Individual pension funds are accumulated over the T periods that the agents work ($\sum_{s=1}^{T} \pi_{t,j}^{ic}(s)m(s)\mu_1$), then they are disaccumulated according to each efficiency j (equation 9), then $PF_{t,j}^{ic}(s) = PF_{t,j}^{ic}(s-1) - P_t^{ic}(s)m(s)\mu_j$ where $s \in (T+1, TR)$. Then the accumulated funds are $\Pi_t = \sum_{s=1}^{T} \pi_{t,j}^{ic}(s)m(s)\mu_1 + \sum_{s=T+1}^{TR} \sum_{j=1}^{2} PF_{t,j}^{ic}(s)$. The accumulated pension funds of the collective capitalization Π_t^{cc} can be expressed in the same way as individual capitalization. The important thing is that the pension agency distributes the funds and in the last period $PF_{t,1}(TR) + PF_{t,2}(TR) = 0$. The aggregate capital is determined by the following equation:

$$K_t = \Omega_t + \Pi_t^{ic} + \Pi_t^{cc} \tag{16}$$

2.5 Government

The government collects income taxes T_t from labor, savings and consumption in order to finance its expenditures on government consumption G_t and social pensions Tr_t. In addition, it confiscates all accidental bequests Beq_t. The government budget is balanced in every period t:

$$G_t + Tr_t = T_t + Beq_t \tag{17}$$

The government spending is a constant fraction of output $G_t = \overline{g}Y_t$. The government's tax revenues are $T_t = \tau_r r_t \Omega_t + \tau_w w_t L_t + \tau_c C_t$. The bequests are a proportion $(1 - \phi(s))$ of savings, $\sum_{s=1}^{T+TR} \omega_{t,j}(s)m(s)\mu_j(1 - \phi_s)$.

3 Computation and calibration

We solve the stationary equilibrium[8] using Python. Following Heer and Maussner (2009), the algorithm solution of steady state and transition are:

Steady state

1. Make initial guesses of the steady state values of the aggregate capital stock K and employment L.
2. Compute the values w, r, which solve the firm's Euler equations and the government budget.
3. Compute the optimal path for consumption, savings, and employment for the new born generation by backward induction given the initial capital stock $k^1 = 0$.
4. Compute the aggregate capital stock K and employment L.
5. Update K and L and return to *step* 2 until convergence.

Transition

1. Choose the number of transition periods t_c.
2. Compute the initial and final steady state solutions for the periods $t = 0$ and $t = t_c + 1$.
3. Provide an initial guess for the time path of the aggregate variables $\{K_t^0 L_t^0\}_{t=1}^{t_c}$.
4. Compute the transition path.
5. Stop if the new value $K_t^1 L_t^1$ is close to the starting value. Otherwise update the initial guess and return to *step 4*.
6. If the aggregate variables in period t_c are not close to those in the new steady state, increase t_c and return to *step 3* using the transition path from the last iteration in the formulation of an initial guess.

8. In the stationary equilibrium the individual variables are normalized by A_t and aggregate quantities by $A_t L_t$. The equations are detailed in Appendix B.

We calibrate an economy with six generations (decades), two productivities ($\{j = 1, 2\}$), and a 30-period transition. Ex-ante heterogeneity follows Heer and Irmen (2014), where the age-efficiency profile is normalized to one and decreases with age. The productivity types are $\{\epsilon_1, \epsilon_2\} = \{1.43, 0.57\}$, consequently high productivity is 2.5 times that of low productivity. The efficiency population is initially calibrated at $\{\mu_1, \mu_2\} = \{0.5, 0.5\}$ and then the effect of lowering the high productivity population to $\{0.3, 0.7\}$ can be seen. Using United Nations data, the population by generation $m(s)$ is calibrated for Chile 2020. The probability of survival $\phi(s)$ is equal to 1 for all ages s.

The coefficient of relative risk aversion $\eta = 2$ and disutility from working $\gamma = 2$ are calibrated so that the aggregate labor supply is 0.4. Labor income share is $\alpha = 0.4$ and depreciation is $\delta = 0.1$. The productivity growth rate is $g_A = 0.01$, the discount factor is $\beta = 0.9$. The capital, employment and consumption tax rates are $\{\tau_r = 0.05, \tau_w = 0.1, \tau_c = 0.1\}$, respectively. The following table summarizes the main calibrated parameters.

Table 1: Calibrated parameters

Parameter	Description	Value
g_a	productivity growth rate	0.01
β	discount factor	0.9
α	production elasticity of capital	0.4
δ	depreciation rate	0.1
τ_w	labor tax rate	0.1
τ_r	wealth tax rate	0.05
τ_c	consumption tax rate	0.1
ρ	updating parameter for method 1	0.001
ψ	parameter of utility function	0.8
η	coefficient of relative risk aversion	2
γ	disutility from working	2

4 Findings

This section shows the main results of implementing the different types of capitalization and mechanisms to redistribute pensions. In section 4.1, the NDC scheme is analyzed in comparison with the FDC system. The steady state and the transition solutions when changing systems are shown. Section 4.2 evaluates adding a tax-financed transfer (NTP) to the individual system. Section 4.3 summarizes the model comparison. Finally, section 4.4 analyzes the consequences of modifying the contribution rate.

4.1 Collective capitalization

This section presents a collective capitalization that guarantees a 50% increase in the low productivity pension with respect to individual capitalization. The high productivity pension is obtained based on the balance of the pension agency described in equation 10. Collective capitalization makes it possible to maintain the levels of capital, employment and aggregate consumption. The redistribution between high and low productivity will depend on the established criteria, in the case of this article, it increases the low productivity pension by 50%.

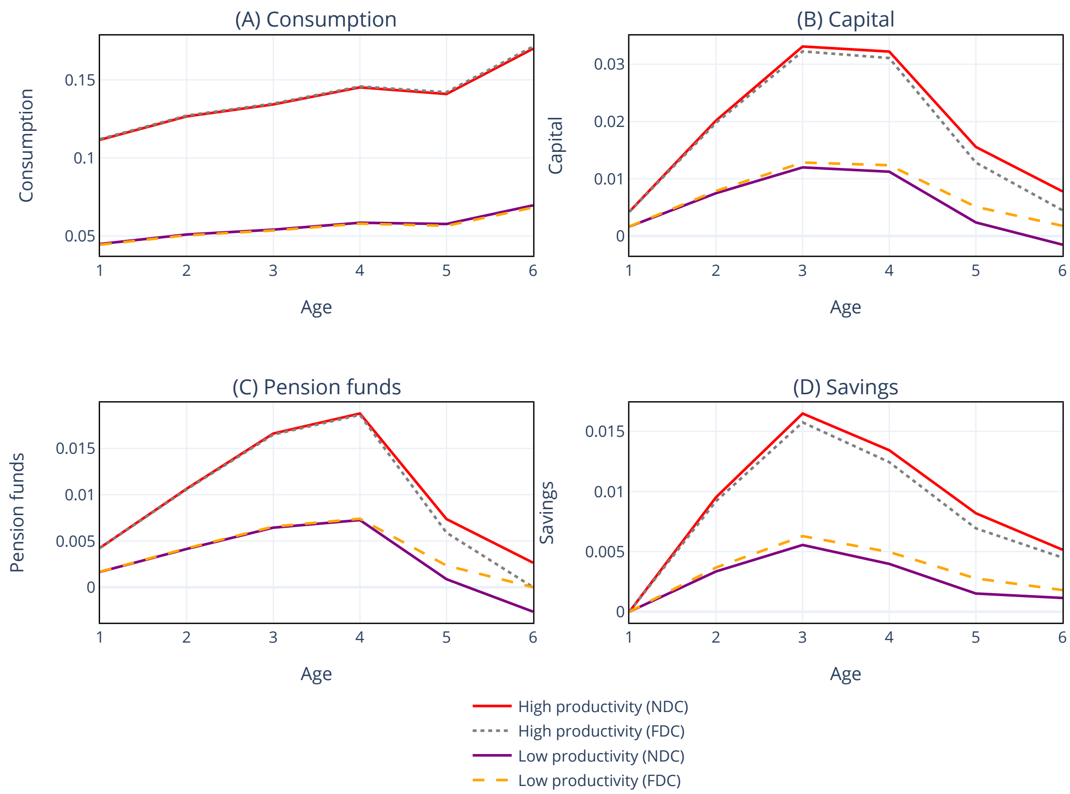
The funds accumulated by both agents go to the aggregate capital, which in both types of capitalization reaches 0.37. Aggregate employment remains at 0.4 and consumption at 0.37. In the aggregate, changing between these two stationary states does not mean a variation, nor is it in prices. There are differences at the individual level by type of generation and productivity. For example, the low productivity pension will increase by 50% (by definition) and the high productivity pension will be reduced by 20%, with an increase in the average replacement rate from 65% to 76%.

The variation in consumption between both systems is low. The aggregate consumption of high productivity retired generations is reduced by 0.8% while low productivity shows an increase of 2.0%. Panel A in figure 5 shows consumption at the individual level by type of productivity in both systems, where the differences are minimal.

The higher pension for low-productivity retirees generates a contraction in the labor supply that ranges from 1.7% in the $s = 1$ generation to 5.1% in the last working age $s = 4$. The contraction of employment reduces income to finance consumption, consequently reducing savings to smooth consumption. The opposite occurs in high-productivity agents (seen in panel D). The pension accounts for 46% of consumption in high productivity and 84% in low productivity in collective capitalization, in contrast with 57% (both) in individual capitalization.

Pension funds are a special case (panel C). To compare the two systems, the collective fund is separated according to the contribution made by each type of agent. In the first four periods they are the same, but in retirement age they differ. In individual capitalization (dotted lines), the funds are accumulated until they reach zero in the last generation. In the collective system in generation 6, the low productivity fund reaches negative values, it withdraws more than it contributed to the fund. The opposite happens in high productivity, where the sum of both is still zero. Capital per generation s (panel B) captures the effect of savings and pension funds.

Figure 1: Behavior per generation and productivity in steady state, individual capitalization and collective capitalization



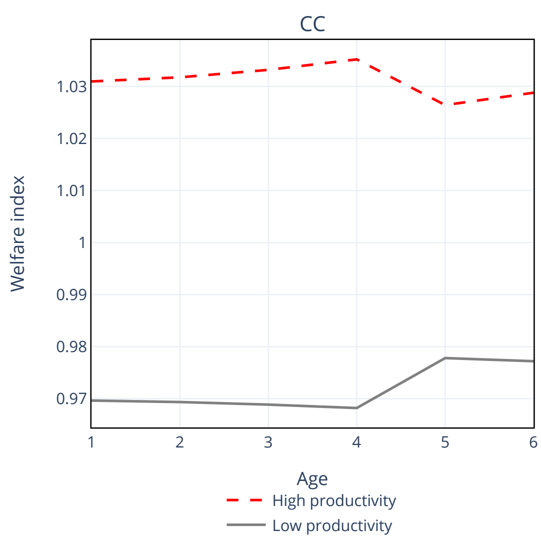
Note: FDC is funded defined contribution, NDC is notional defined contribution.

Following Galaasen (2009) and Auerbach and Kotlikoff (1987), we develop a measure of welfare effect. The *welfare index*[9] ($W(s)$) is one when utility does not change; values lower than one imply an improvement in household welfare. Figure 2 shows the welfare index by generation and type of productivity. High-productivity

9. The welfare index ($W(s)$) is obtained from present value utilities between new scenario (N) and benchmark (B): $W_t(s) = \frac{PVU_t^N(s)}{PVU_t^B(s)}$, where $PVU_t(s) = \beta^{s-1}u(c_{t+s-1}(s), l_{t+s-1}(s))$, for each generation s.

people have lower well-being (values greater than one) throughout the life cycle. On the other hand, people with low productivity show better systematic in all generations (values less than one). This is due to higher consumption and lower employment. The aggregate welfare improves in this specification, reaching a value less than one of W = 0.99.

Figure 2: Welfare per generation and productivity in steady state, collective capitalization over individual capitalization



Note: Values less than one indicate an increase in welfare.

Figure 3 shows the transition between the two capitalization systems, starting from the individual system. The red lines show high productivity, and the gray lines low productivity, the sum of both gives the aggregate variable. This exercise allows us to see how the effect of the transition is distributed in the face of a change that maintains the aggregate variables almost constant. Panels A, B, and C show capital, pension funds[10], and savings, respectively. In all three cases, it is observed that

10. In individual capitalization, to exemplify the transition between high and low productivity agents it is clear that both have separate funds. The funds accumulated by each type are shown, despite the fact that a common fund is used to deliver pensions.

there is a period of six years where the level of low productivity increases and the level of high productivity decreases. Then a constant transition to the new steady state is observed where the low productivity level decreases in contrast to the high productivity level.

Panels D and E show aggregate employment and consumption, respectively. In both cases, it is observed that there is no change between the two types of capitalization. Consequently, the collective system allows redistribution without aggregate changes in capital, employment and consumption, but modifies savings and capital at the level of productivity.

One relevant exercise is to see how the system behaves according to changes in the proportion of the population by productivity. Table 2 summarizes the change in the initial exercise from $\{\mu_1 = \mu_2 = 0.5\}$ to $\{\mu_1 = 0.3, \mu_2 = 0.7\}$, that is, an economy where the low-productivity population predominates.

Reducing the proportion of high productivity means lowering the financing capacity of the collective fund. If the low productivity pension is maintained at $\hat{P} = 0.09$, the high productivity pension falls by 33%, falling below the low productivity pension. This occurs because the pension agency distributes the remaining resources to balance the budget according to equation 10. Low productivity aggregate consumption and savings increase by 40% due to the effect of the increase in μ_2. Consequently, in this model, redistribution is determined by the financing capacity, which depends on the percentage of the population with high productivity. With a high productivity ratio of 30%, a low productivity pension of 0.9 can be financed, without lowering the high productivity pension, with a contribution rate of 11.5%.

Figure 3: Transition from individual to collective capitalization

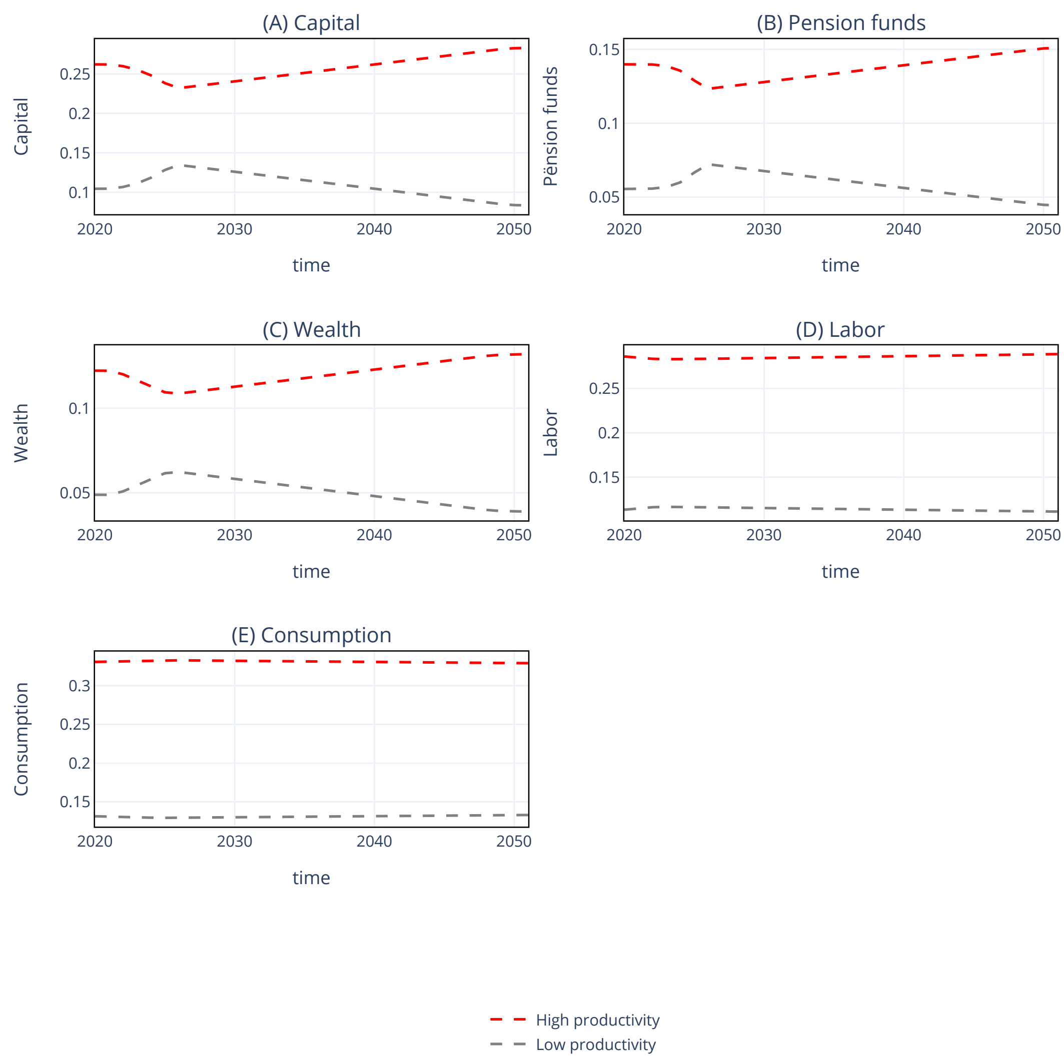


Table 2: The effect of changing the population of high and low productivity in the collective capitalization system

	NDC (1)	NDC (2)	Δ% (3)
Population proportion			
High (μ_1)	50%	30%	
Low (μ_2)	50%	70%	
Pension			
Inequality	1.34	0.9	−33%
High	0.12	0.08	−33%
Low	0.09	0.09	0%
Aggregate consumption			
High	0.13	0.08	−38%
Low	0.05	0.07	40%
Aggregate wealth			
High	0.052	0.034	−35%
Low	0.015	0.021	40%

Note: NDC is notional defined contribution.

4.2 Non-contributory pension

An additional exercise is to evaluate the effect of a non-contributory pension (NTP) that shares the risk through general taxes. For this, the government delivers a transfer to low-productivity households, in line with equations 11 and 17, from a balanced budget. This exercise jointly carries out an FDC pension ($tau = 10\%$), plus a NTP that increases the low productivity pension by 50%.

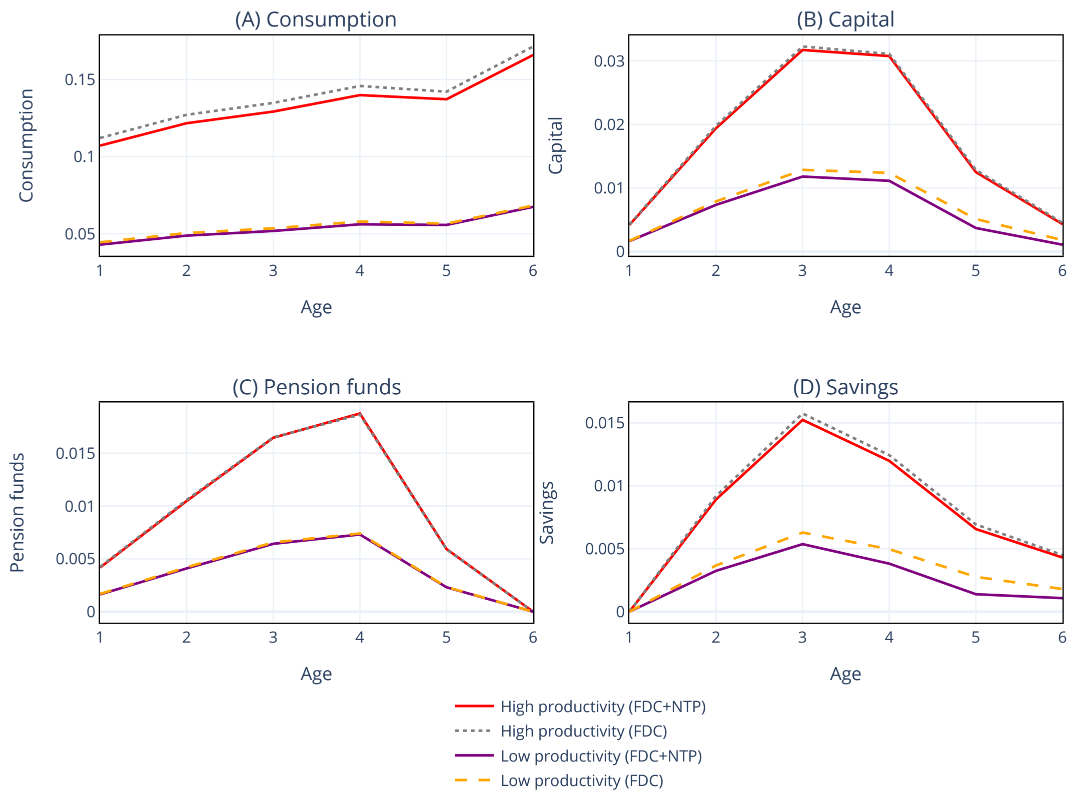
A risk-sharing mechanism through general taxes generates lower capital for low-productivity agents. This can be seen in panel B of Figure 4, where the purple line is systematically under the green dotted line. This change, especially among retirees, is more moderate than in collective capitalization (Figure 5) and maintains the individual level of consumption (panel A). A positive income shock in low-productivity agents generates lower savings (panel D) without changing pension funds (panel C) and without changing high-productivity savings and pension funds.

Increasing the low productivity pension by 50% with a NTP sreduces the inequality ratio from 2.5 to 1.7. Additionally, the average replacement rate is increased from 65% to 68%. This system implies a loss of efficiency. Implementing this change generates a 2.7% increase in the interest rate r and a 3.8% reduction in aggregate capital K, explained by a 8.5% drop in aggregate savings. The effect on wage w and aggregate employment is close to 1% drop.

This exercise modifies the individual savings behavior of low-income households, but not high-income households. Here it was assumed that for the same level of taxes $\{\tau_r, \tau_c, \tau_w\}$, part of the government budget was used to finance the pension $P^{sp}_{t,j}(s)$. The financing capacity of the transfer depends on the collection. In Appendix C, an exercise is carried out on the economy's response to different levels of taxes and collection according to the proportion of the population with high and low productivity.

Figure 5 shows the loss of welfare in high and low productivity, in the NTP system with FDC. To finance the non-contributory pension, tax rates of $\tau_w = \tau_r =$

Figure 4: Behavior per generation and productivity in the steady state, individual capitalization and individual capitalization with social pension

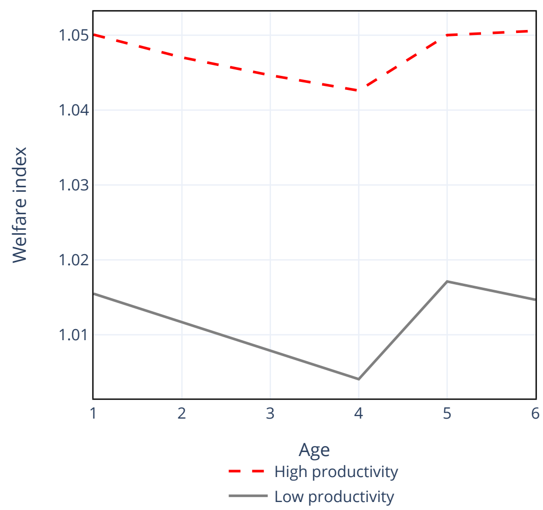


Note: FDC is funded defined contribution, NTP is non-contributory targeted pension.

$\tau_c = 0.014$ are used. The increase in taxes generates a distortion in the economy that decreases welfare in both types of productivities in all generations. The aggregate welfare is 1.02, that is, a welfare loss.

The following exercise shows how welfare is reduced by type of tax. For this, the tax rate is calibrated in order to guarantee a 50% increase in the low productivity pension with respect to FDC. The three types of taxes are used separately, where $\tau_w = 0.034$, $\tau_r = 0.135$ and $\tau_c = 0.0295$. Figure 6 shows the result by type of tax,

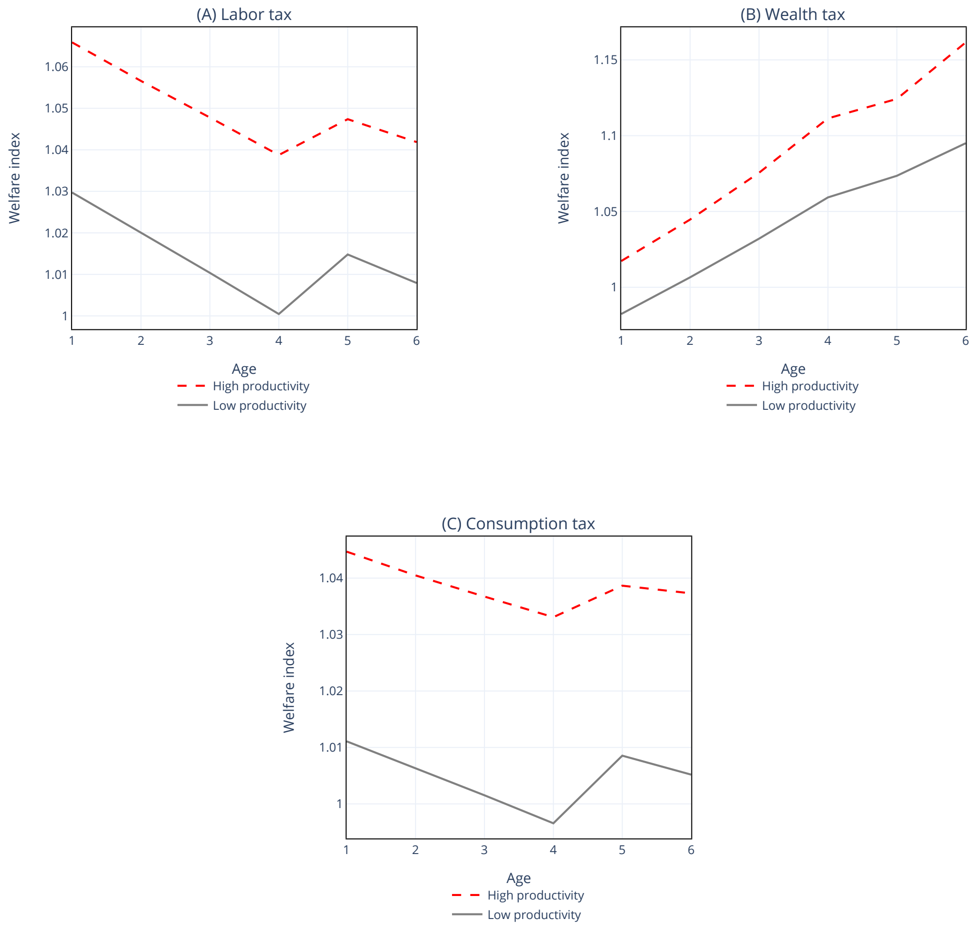
Figure 5: Welfare per generation and productivity in steady state, social pension over individual capitalization



Note: Values less than one indicate an increase in welfare.

type of productivity and generation. The first thing that stands out is that the three types of taxes generate a welfare loss with respect to FDC. Second, the welfare loss decreases with age in the employment and consumption tax, while in the wealth tax the welfare loss increases with age. In all of them it is maintained that the one with high productivity is worse off than the one with low productivity. Finally, the aggregate welfare deteriorates more with the capital tax ($W = 1.067$), followed by the labor tax ($W = 1.052$) and finally the consumption tax ($W = 1.039$). The effects of increasing each type of tax can be seen in detail in Appendix C.

Figure 6: Welfare index by type of tax, productivity and age



Note: The three specifications imply a 50% increase in the low productivity pension, financed only with one type of tax. For this pension increase, the tax rates are calibrated at $\tau_w = 0.034$, $\tau_r = 0.135$ and $\tau_c = 0.0295$ respectively. Values less than one indicate an increase in welfare.

4.3 Comparing models

A overview of the main aggregate variables is found in table 3. We use FDC as a point of comparison (*column 1*). NDC (collective capitalization) is shown in *column 2* and NTP is in *column 3*. NDC has the lowest rate of inequality in pensions, because the low-productivity pension increases and the high-productivity one decreases. This is observed in *column 2* and in the high and low productivity replacement rates. The NTP scheme allows for a reduction in the gap without reducing the pension in $j = 1$; consequently, the ratio is 1.69. Including taxes implies lower revenues, so the replacement rate increases in column 3.

Interestingly, NDC maintains the prices of the individual system, since it maintains the aggregate levels of capital and employment. Redistribution take place at the level of individual savings, consumption and obviously pensions. This means an aggregate welfare gain with no efficiency losses, but a welfare loss for high-productivity households. NTP system has small changes in the aggregate variables, the pension funds rise from 0.196 to 0.197, and savings fall one percentage point, decreasing the level of aggregate capital. The salary falls from 0.401 to 0.395, and the interest rate rises from 0.63 to 0.65. In the first two models, aggregate consumption is maintained, while in NTP it decreases 1 percentage point.

Using NDC, can be redistributed through the pension system. Collective capitalization makes it possible to maintain aggregate savings, reduce inequality and improve the aggregate welfare. The cost is transferred to high productivity, but the magnitude depends on the population of high and low productivity. When redistributed through taxes, such NTP, a target pension is effective in reducing inequality, however, the magnitude and distortions depend on the financing capacity.

Table 3: Performance of the different models

	FDC	NDC	(1) + NTP
	(1)	(2)	(3)
Pensions			
Pension inequality	2.52	1.33	1.74
Replacement rate	0.65	0.76	0.86
Rep. rate high	0.65	0.52	0.68
Rep. rate low	0.65	1.01	1.04
Prices			
Interest rate (r)	0.63	0.63	0.65
Wage (w)	0.4	0.4	0.4
Aggregate variables			
Capital (K)	0.37	0.37	0.35
Pension funds (Π)	0.195	0.195	0.196
Wealth (Ω)	0.17	0.17	0.16
Labor (L)	0.4	0.4	0.39
Consumption (C)	0.46	0.46	0.45
Welfare (W)	1.0	0.99	1.02

Note: FDC is funded defined contribution, NDC is notional defined contribution and NTP is non-contributory targeted pension.

4.4 Contribution rate increase

This section analyzes the increase in the contribution rate and its effect on the main variables of the collective capitalization model. Specifically, values between 0.05 and 0.15 are evaluated, keeping the low-productivity pension above that of the individual capitalization model with $\tau_{ic} = 0.1$.

The increase in the contribution rate allows the replacement rate to be increased linearly; this can be seen in the second column of table 4. If we keep the low-productivity pension constant, the high-productivity pension can be increased because there is a larger accumulated pension fund. In column 3, you can see the increase in the average pension, driven by the increase in high productivity. Similarly, the ratio of high pension over low productivity pension ranges from 0.23 to 2.34. However, increasing the contribution rate means more chance of increasing low-productivity pensions, and thus redistributing.

Wages (column 5) increase the contribution rate; meanwhile, the interest rate (column 6) decreases. This is explained by the growth of aggregate capital versus the increase in the contribution. By tripling the contribution rate, the salary changes by 14% and the interest rate by -20%.

Pension funds (column 8) move in the same direction as the contribution rate, while savings (column 9) move in the opposite direction. A rate of up to 7% dominates the aggregate savings on the pension funds; then, the funds steadily become more relevant. The aggregate capital follows the movement of the pension funds that triple between the rates of 5% and 15%, in contrast to the savings that are reduced by half. Aggregate employment and consumption are quite inelastic to changes in the contribution rate, as shown in columns 10 and 11.

Section 4.1 showed that the collective system approximates the aggregate results of the individual model. The main differences occur when redistributing between high-productivity agents and low-productivity agents. Something similar occurs when the contribution rate changes. Figure 11 in Appendix D shows the change in the variables against different values of τ in collective and individual capitalization. Prices, average pension, capital, employment and consumption move in a similar

Table 4: Performance of the model against changes in the contribution rate, collective capitalization

Contribution Rate (1)	Replacement rate (2)	Average pension (3)	Pension ratio (4)	Wage (5)	Interest rate (6)	Aggregate capital (7)	Pension funds (8)	Aggregate Wealth (9)	Aggregate labor (10)	Aggregate consumption (11)
0.05	0.68	0.06	0.23	0.36	0.76	0.28	0.10	0.18	0.40	0.37
0.06	0.73	0.07	0.46	0.37	0.74	0.29	0.12	0.17	0.40	0.37
0.07	0.78	0.08	0.69	0.37	0.72	0.30	0.14	0.16	0.40	0.37
0.08	0.82	0.09	0.91	0.38	0.70	0.31	0.16	0.16	0.40	0.37
0.09	0.87	0.10	1.12	0.38	0.69	0.32	0.18	0.15	0.40	0.37
0.10	0.91	0.11	1.34	0.39	0.67	0.33	0.20	0.14	0.40	0.37
0.11	0.96	0.12	1.54	0.39	0.66	0.35	0.22	0.13	0.39	0.37
0.12	1.01	0.13	1.75	0.40	0.64	0.36	0.23	0.12	0.39	0.37
0.13	1.06	0.14	1.95	0.40	0.63	0.37	0.25	0.11	0.39	0.37
0.14	1.11	0.15	2.15	0.41	0.62	0.38	0.27	0.10	0.39	0.37
0.15	1.16	0.16	2.34	0.41	0.61	0.39	0.29	0.09	0.39	0.37

way. Replacement rates are higher in the collective system, and in the individual system, the high/low pension ratio remains constant according to productivity differences.

5 Chilean application

In this section, we perform a calibration of the Chilean economy. First, we use the population distribution for the year 2020 according to United Nations data. Second, we use a high and low productivity population distribution of $30 - 70\%$. Based on this population distribution and using data from the "Supplementary Income Survey" of the Chilean National Institute of Statistics for the year 2020, the 30% with the highest income have 4.13 times the income of the 70% with the lowest income. Consequently, we calibrate the ratio of high over low productivity at 4.

Additionally, we calibrated $\alpha = 0.35$ and $\beta = 0.99$ so that $\frac{wL}{Y} = 0.61$. These parameters are in line with Heer (2003). The consumption tax τ_c is 19% like the VAT, the capital tax τ_r remains similar to the first category tax at 25%, while the employment tax[11] is 10%. The rest of the parameters remain the same as in table 1. Finally, data from the Superintendency of Pensions show that, on average, self-funded pensions increased by 17% when supplemented with solidarity contributions (Aporte Previsional Solidario, APS) in December 2020. The NTP is calibrated as a transfer that increases the low-productivity individually funded pension by 17%.

Table 5 summarizes the main results for the Chilean calibration. Model 1 shows individual capitalization only. It captures the ex ante heterogeneity in the labor market and population. Additionally, in this model, the replacement rate is 59% without pension gaps. According to Comisión asesora presidencial (2015), the effective replacement rate between 2007-2014 for groups with contribution greater than 75% is 46%. The replacement rate for the group with contributions between $80 - 100\%$ reaches an average of 47% based on 2016 administrative information from the Chilean Superintendence of Pensions (Zilleruelo 2017).

In model 2, a NTP is added to the low-productivity individual contributions (such as APS in Chile). This transfer, financed with general taxes, increases the low-productivity pension by 17%. This model generates very few distortions in relation to model 1. The main effect is it to increases the low productivity pension

11. The labor tax in Chile is progressive, with marginal rates between 4% and 40%. However, the exemption limit is higher than the median income in Chile. For this reason, a similar rate was left for the second bracket, but a differentiated tax scheme could be developed in future research.

and reduces the gap from 4.01 to 3.43.

As shown theoretically in section 2.2 and empirically in section 4.1, the collective system: i) approximates the results of the individual system, ii) allows redistribution by fixing the minimum low productivity pension and the rest is distributed by the pension agency, and iii) allows distribution depending on the proportion of the population with high and low productivity. Finally, an exercise is carried out to add a 2.5% contribution through a collective fund, i.e., a model with a 10% contribution to the FDC system, NTP that raises the low-productivity pension by 17% and 2.5% in NDC scheme. The collective contribution will be used to increase the low-productivity pension in the individual system. Then, the low productivity pension will be $P_2 = P_2^{ic} + P_2^{ps} + P_2^{cc}$, where $P_2^{ps} = 0.17 \cdot P_2^{ic}$ and P_2^{cc} guarantee a replacement rate of one.

Model 3 shows the main results of adding the collective contribution. First, this exercise allows lowering inequality in pensions from 3.43 to 2.77. The replacement rate for high productivity increases from 60% to 67% (less than if all the contribution to their fund went to their pension), while for low productivity, it rises from 70% to 100%. Here the redistribution effect is direct, we use the 2.5% collective contribution to increase the low productivity pension of individual capitalization. Higher capital lower the interest rate by two percentage points and increases wages by one percentage point. The lower interest rate lowers household savings by 20%, while aggregate employment falls by one percentage point. Aggregate consumption remains constant with respect to model 2. This exercise implies an improvement in welfare with respect to model 2. The welfare index between model 3 and 2 is equal to 0.99.

The individual effects of moving from model 2 to model 3 are shown in Figure 7. Individual consumption is reduced for high productivity individuals and is maintained for low productivity (panel A). Pension funds (panel C) increase in both agents due to the increase in the collective contribution rate, while savings (panel D) are reduced in all generations and productivities due to the lower return. Capital (panel B) by generation and productivity captures both effects but is dominated by pension funds. As in section 4.1, two points should be emphasized. Pension funds in generation 6 become negative; i.e., it receives more than it contributes, and this

Table 5: Performance of the different models

	FDC	(1) + NTP	(2) + NDC
	(1)	(2)	(3)
Pensions			
Pension inequality	4.01	3.43	2.77
Replacement rate	0.59	0.67	0.9
Rep. rate high	0.59	0.6	0.67
Rep. rate low	0.59	0.7	1.0
Prices			
Interest rate (r)	0.49	0.5	0.48
Wage (w)	0.49	0.49	0.5
Aggregate variables			
Capital (K)	0.44	0.44	0.46
Pension funds (Π)	0.24	0.24	0.30
Wealth (Ω)	0.2	0.2	0.16
Labor (L)	0.94	0.93	0.92
Consumption (C)	0.42	0.43	0.43
wL/Y	0.61	0.61	0.60

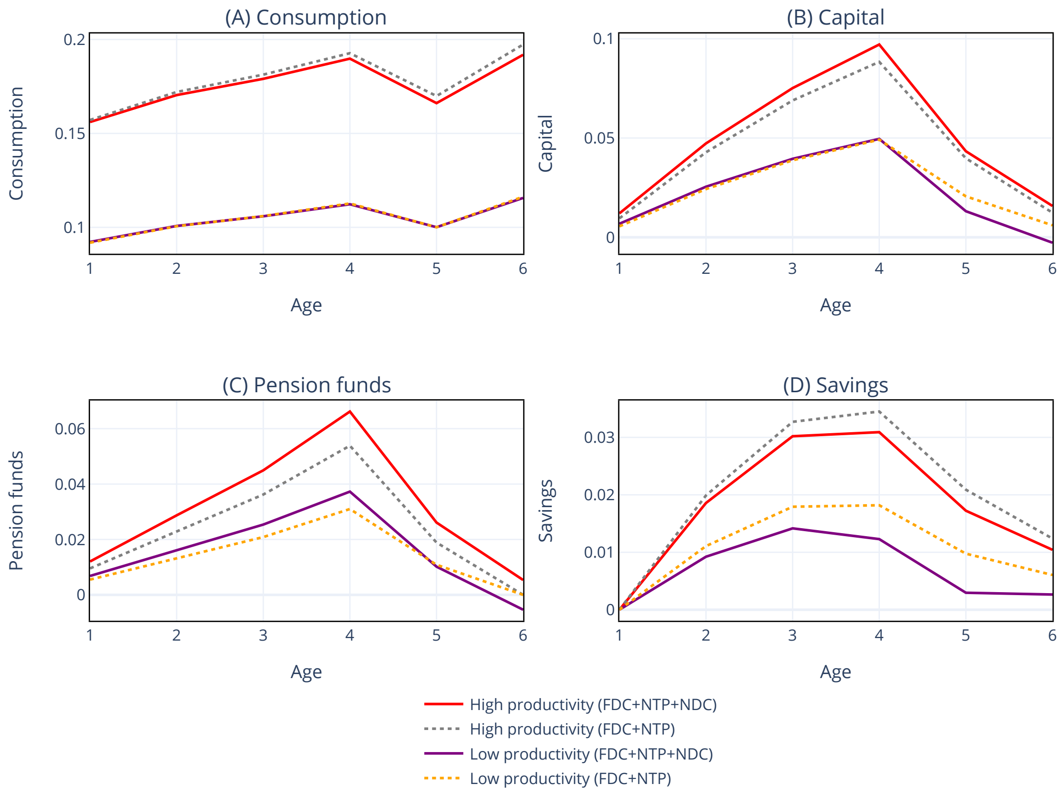
Note: FDC is funded defined contribution, NDC is notional defined contribution and NTP is non-contributory targeted pension.

reflects redistribution. On the other hand, the lower interest rate, lower labor supply and higher pensions lead to the fact that the dis-savings of generations 5 and 6, with low productivity reach negative values.

The transition is financed by high-productivity individuals. Figure 9 shows the transition between models 2 and 3 over a 30-year period. At the beginning, the rate increase pushes up both pension funds (panel B), then the low-productivity one starts to moderate. The most significant effect is observed in savings (panel C), where there is a significant drop in the high productivity (red line), which then increases as the years go by, while the low productivity decreases progressively.

The growth of high-productivity capital (panel A) is moderated by the fall in savings, despite the increase in pension funds. In contrast, low-productivity capital

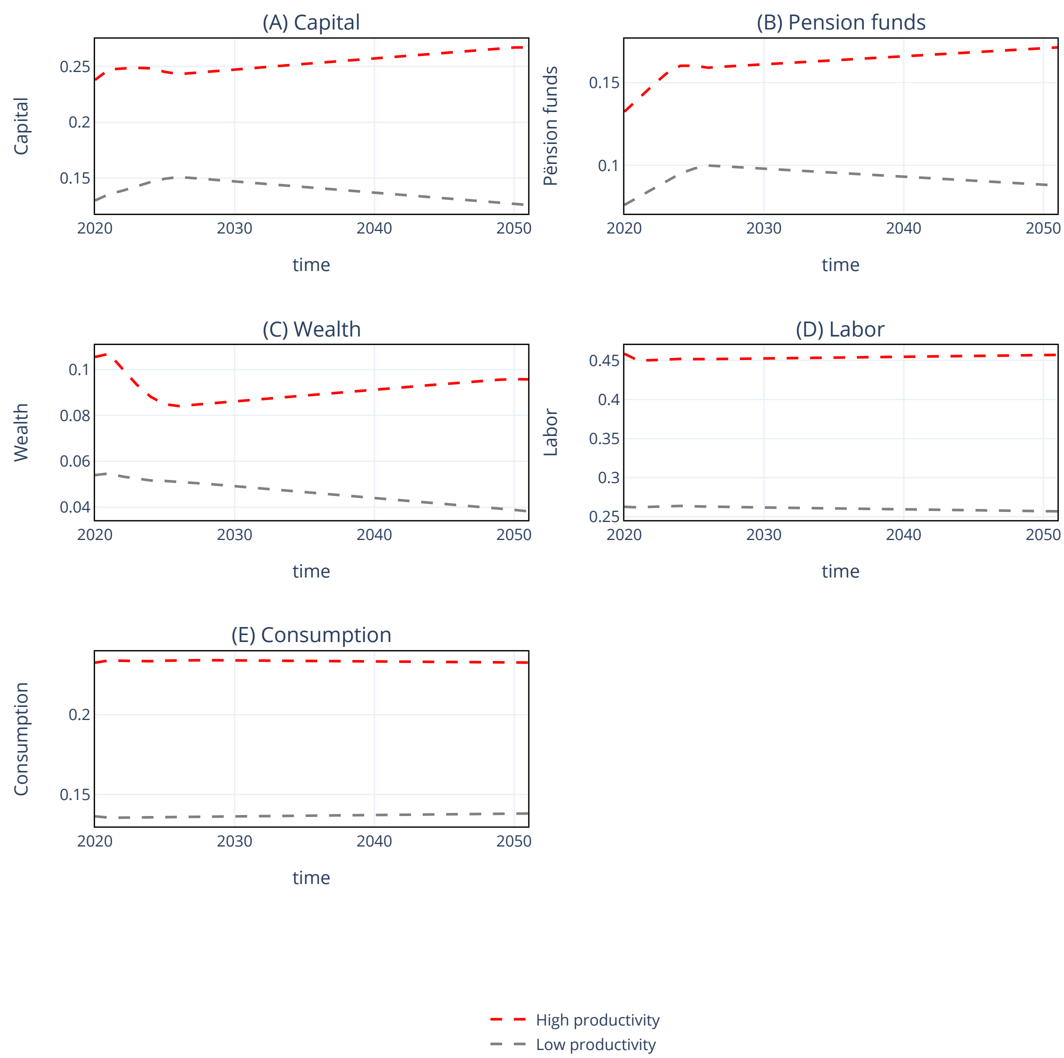
Figure 7: Individual variables in model 2 and model 3



Note: FDC is funded defined contribution, NDC is notional defined contribution and NTP is non-contributory targeted pension.

increases initially (due to pension funds) and then decreases steadily due to both effects. Consumption (panel E) and employment (panel D) do not have major changes in the transition.

Figure 8: Transition from model 2 to model 3, aggregated variables according to productivity



6 Conclusions

This paper quantifies the consequences on inequality, efficiency and welfare of changing the pension system. For this, a model of overlapping generations is introduced in a context of perfect foresight, ex-ante heterogeneity and a closed economy. The main contribution of this research is to show two redistribution mechanisms in capitalization systems. A funded defined contribution (FDC) system is compared with a notional defined contribution (NDC) scheme with collective capitalization, and another that redistributes based on general taxes with non-contributory targeted pension (NTP).

Redistribution through the pension system is quite effective. By using a pension agency that guarantees a minimum for low-productivity agents and distributes the remaining funds among high-productivity agents, it is possible to use an NDC scheme that capitalizes as in an individual system and shares the resources. This system does not distort the aggregate variables of the economy and allows reallocation from high to low productivity agents. This mechanism is effective in reducing inequality and increasing welfare, without losing efficiency. However, the high and low productivity population determines the capacity to redistribute. The fewer high-productivity people the economy has, the more difficult it is to redistribute.

General taxes are another effective way to redistribute. In this case, a direct transfer to low-productivity individuals through taxes on capital, employment and consumption was used. The NTP makes it possible to increase the replacement rate of the least productive agents without altering the pension of the most productive. However, the capacity to redistribute depends on tax rates, government budget and population distribution. The non-contributory pension effectively reduces inequality in retirement but reduces the economy's capital, consumption and aggregate welfare. The consumption tax was shown to be less distorting than the employment and wealth tax.

In addition, the model was calibrated to the Chilean economy, specifically to the difference in productivity, population, share of employment in the product and replacement rate. A non-contributory pension was included, such as the Solidarity Pension Contribution, and an additional contribution of 2.5% in NDC to increase the low-productivity pension until a replacement rate of 100% is obtained. The main consequences are a significant increase in the replacement rate of low-productivity, a reduction of inequality in old age, an increase in aggregate capital driven by higher pension funds, a decrease in the interest rate and household savings, and an improvement in welfare. The greatest cost during the transition is paid by high-productivity individuals, who in the early years significantly reduce their savings.

Some exercises for future research include increasing the number of generations, thus having more smoothed results. A relevant aspect of this model is that it uses a closed economy; therefore, the interest rate is solved endogenously and does not show the possibility of foreign financing; consequently, it would be interesting to compare the results between a closed and an open economy such as in Attanasio, Kitao, and Violante (2007). Additionally, in this economy, there are no idiosyncratic risks, so extending to a stochastic model can give greater realism to the labor and life cycle of the agents.

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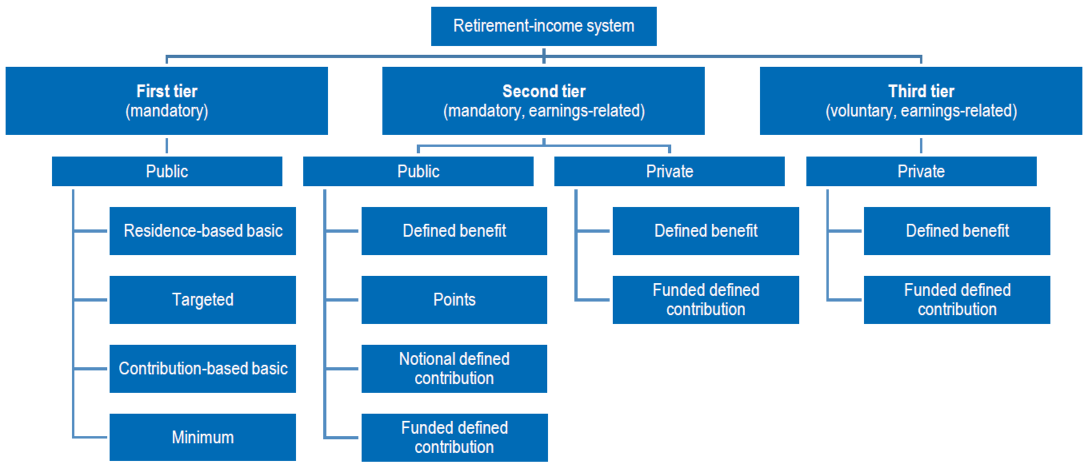
A Pension systems

Figure 9: Different types of retirement-income provision



Source: OECD (2021).

B Stationary model

To express the equilibrium in terms of stationary variables we divide aggregate quantities by $A_t L_t$ and individual variables and prices by A_t. The aggregate stationary variables are:

$$
\begin{array}{lll}
k_t \equiv \frac{K_t}{A_t L_t} & \tilde{B}eq_t \equiv \frac{Beq_t}{A_t L_t} & \tilde{T}_t = \frac{T_t}{A_t L_t} \\
\tilde{G}_t = \frac{G_t}{A_t L_t} & \tilde{C}_t = \frac{C_t}{A_t L_t} & \tilde{Y}_t = \frac{Y_t}{A_t L_t}
\end{array}
$$

and stationary individual variables:

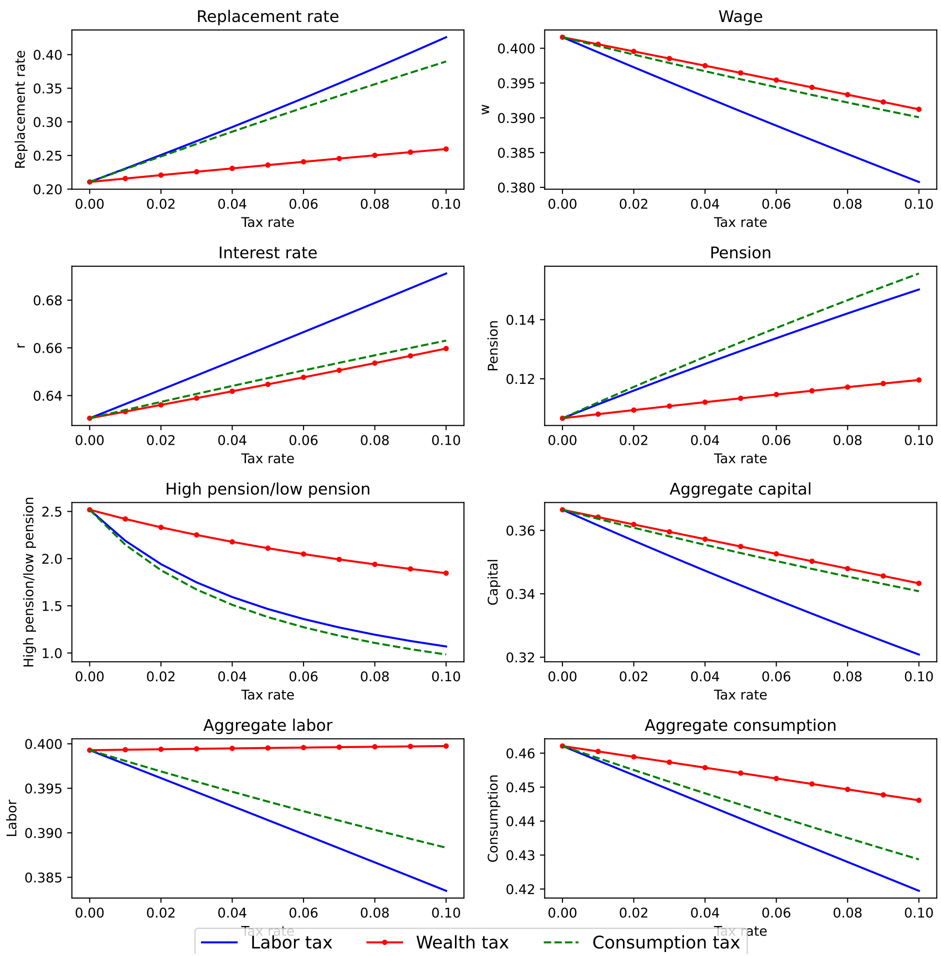
$$
\begin{array}{lllll}
\tilde{c}_t \equiv \frac{c_t}{A_t} & \tilde{w}_t \equiv \frac{w_t}{A_t} & \tilde{\pi}_t^{ic} \equiv \frac{\pi_t^{ic}}{A_t} & \tilde{\pi}_t^{cc} \equiv \frac{\pi_t^{cc}}{A_t} & \\
\tilde{P}_t^{ic} \equiv \frac{P_t^{ic}}{A_t} & \tilde{P}_t^{cc} \equiv \frac{P_t^{cc}}{A_t} & \tilde{P}_t^{sp} \equiv \frac{P_t^{sp}}{A_t} & \tilde{\omega}_t \equiv \frac{\omega_t}{A_t} & \tilde{tr}_t \equiv \frac{tr_t}{A_t}
\end{array}
$$

C Financing capacity using taxes

Table 6: Pensions according to the individual capitalization system and solidarity pension using different tax systems

	Labor tax		Wealth tax		Consumption tax	
Tax rate	P_1^{ic}	P_2^{ic}	P_1^{ic}	P_2^{ic}	P_1^{ic}	P_2^{ic}
0.00	0.15	0.06	0.15	0.06	0.15	0.06
0.01	0.15	0.07	0.15	0.06	0.15	0.07
0.02	0.15	0.08	0.15	0.07	0.15	0.08
0.03	0.15	**0.09**	0.15	0.07	0.15	**0.09**
0.04	0.15	0.10	0.15	0.07	0.15	0.10
0.05	0.15	0.10	0.15	0.07	0.15	0.11
0.06	0.15	0.11	0.15	0.08	0.15	0.12
0.07	0.15	0.12	0.15	0.08	0.15	0.13
0.08	0.15	0.13	0.15	0.08	0.15	0.14
0.09	0.15	0.14	0.15	0.08	0.15	0.15
0.10	0.16	0.15	0.16	0.08	0.15	0.16
0.11	0.16	0.15	0.16	**0.09**	0.15	0.17

Figure 10: Performance of the model against changes in the contribution rate, individual and collective capitalization



D Contribution rate increase

Figure 11: Performance of the model against changes in the contribution rate, individual and collective capitalization

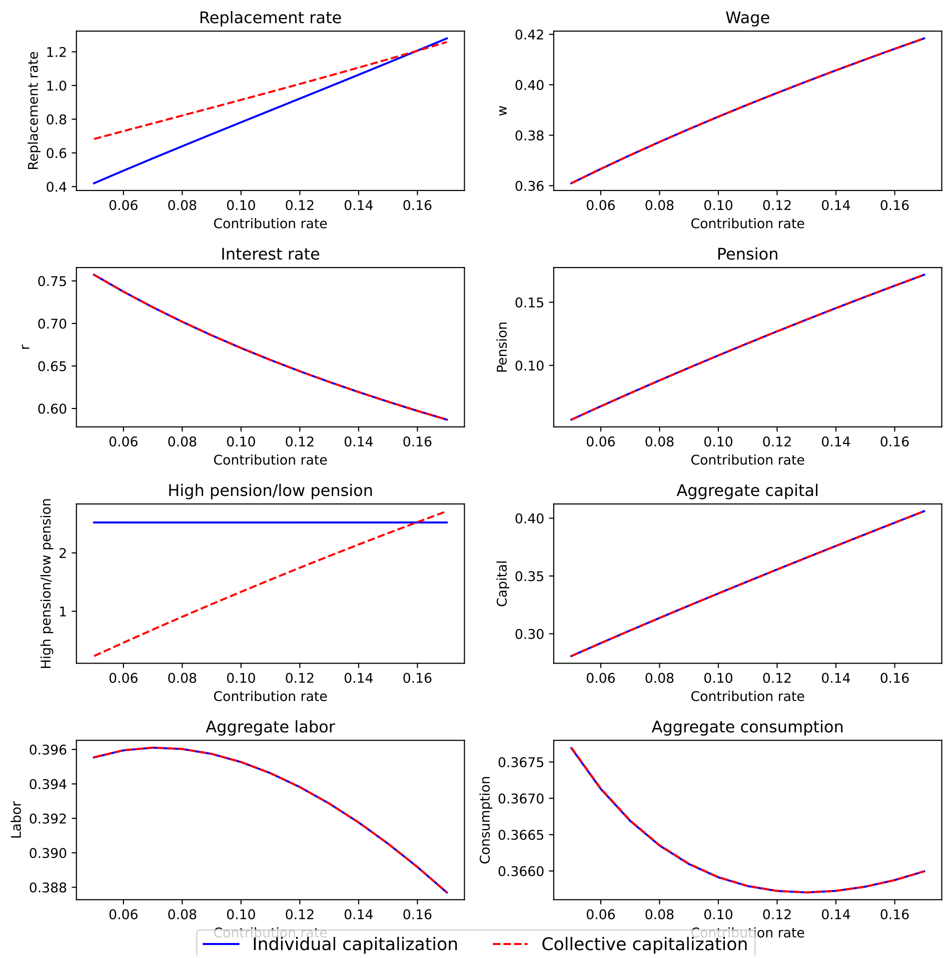


Table 7: Performance of collective capitalization

τ_{cc}	L_1	L_2	C_1	C_2	Ω_1	Ω_2	Π_1	Π_2	K_1	K_2
0.05	0.27	0.1	0.19	0.08	0.15	0.03	0.09	0.01	0.24	0.04
0.06	0.27	0.1	0.20	0.08	0.14	0.03	0.10	0.01	0.24	0.05
0.07	0.27	0.1	0.20	0.08	0.13	0.03	0.12	0.02	0.25	0.05
0.08	0.27	0.1	0.20	0.08	0.12	0.03	0.13	0.03	0.25	0.06
0.09	0.27	0.1	0.20	0.08	0.12	0.03	0.14	0.04	0.26	0.07
0.10	0.27	0.1	0.20	0.08	0.11	0.03	0.15	0.04	0.26	0.07
0.11	0.27	0.1	0.20	0.08	0.10	0.03	0.16	0.05	0.27	0.08
0.12	0.27	0.1	0.20	0.08	0.09	0.03	0.18	0.06	0.27	0.09
0.13	0.27	0.1	0.20	0.08	0.09	0.03	0.19	0.07	0.27	0.09
0.14	0.27	0.1	0.20	0.08	0.08	0.03	0.20	0.07	0.28	0.10
0.15	0.27	0.1	0.20	0.08	0.07	0.03	0.21	0.08	0.28	0.11