Public redistributive policies in general equilibrium: An application to Greece*

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Abstract

We develop a general equilibrium OLG model of a small open economy to quantify the aggregate and distributional implications of a wide menu of public redistributive policies in a unified context. Inequality is driven by unequal parental conditions in financial and human capital. The model is calibrated and solved using fiscal data from Greece. Our aim is to search for public policies, targeted and non-targeted, that can reduce income inequality without damaging the macroeconomy and without worsening the public finances. Pareto-improving reforms that also reduce inequality include an increase in public education spending provided to all and an increase in the inheritance tax rate on financial wealth. At the other end, we identify reforms that may reduce inequality but make everybody worse off. Regarding cases in between, a switch to a fully funded public pension system is good for everybody although it is the rich-born that benefit more by moving to a more efficient macroeconomy.

Keywords: Inequality, efficiency, public policy.

JEL classification: D3, H3, H5.

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1 Introduction

Concerns over growing inequality of income and wealth have been at the center of public and policy debate in recent years, especially since the outbreak of the 2008 global financial crisis.[1] The rise in inequality in several countries has led to new calls for redistributive policies. Greece is not an exception. Actually, Greece scores poorly in terms of inequality. It has one of the highest inequality levels in the European Union as measured by e.g. the Gini coefficient or the poverty rate (see section 2 below for details). It also features relatively high inter-generational persistence in inequality which means that there is a strong transmission of parental (dis)advantages that works as an obstacle to income mobility and hence to equality (again see section 2 for details). At the same time, with a public debt-to-GDP ratio around 200%, there is no fiscal room for the adoption of extensive social policies if the latter further weaken the situation of public finances.

In this paper, we develop a general equilibrium model to evaluate a wide menu of commonly debated redistributive policies when inequality is driven by differences in initial conditions.[2] The model is applied to the Greek economy. Our aim is to search for public policies that can reduce inequality without damaging the economy's growth prospects and without increasing the already high public debt-to-GDP ratio.

The vehicle used for our analysis is a medium-scale overlapping generations (OLG) model of a small open economy.[3] Regarding households, there are two distinct types that differ in the initial levels of financial and human capital which both depend on their family background; we call them rich-born and poor-born households. Each type can live for three periods as young, adult and old in an OLG setup. But choices, skills, income and wealth, in all three periods, can differ depending on one's initial conditions. For example, contrary to the poor-born, the rich-born start with financial wealth and enough human capital which both allow them to get skilled jobs and to participate in asset markets in their adult life.[4] [5] Regarding firms, given the evidence that skill-biased technological progress is behind the wage premium to skilled workers (the so-called skill premium), we use the technology introduced by Stokey (1996) and Krusell et al (2000) according to which capital accumulation is more complementary to skilled labor than to the unskilled one; hence the skill premium enjoyed by the rich-born in their adult life. Regarding the government, we have a rich menu of public spending items and taxes. Spending-tax policies are embedded into the model in a

[1] See e.g. Bourguignon (2015, 2018).

[2] That is, in our paper, differences in earnings and wealth across agents result from ex ante heterogeneity in initial conditions transmitted from parents and grandparents to their children (see below for the related literature). Another type of heterogeneity can be ex post shocks as in e.g. the Aiyagari-Bewley literature. For a review of theories of inequality, see e.g. Quadrini and Rios-Rull (2014).

[3] There is a rich literature on OLG models with fiscal policy. But, to the best of our knowledge, none of the previous papers has studied all the main public policies in a unified general equilibrium framework and their role in both efficiency and equality.

[4] As already said, this setup is supported by evidence that initial conditions (father-son relationship or inter-generational correlation) play an important role in shaping opportunities over life thereby affecting (in)equality persistence. See e.g. Glomm and Ravikumar (1992), Galor and Zeira (1993), Benabou (1996), Cunha and Heckman (2007), Ehrlich and Kim (2007), Huggett et al (2011), Corak (2013), Heckman and Mosso (2014), Autor (2014), Francesconi and Heckman (2016), De Nardi and Fella (2017), Abott et al (2019) and Dettmer et al (2020). For Greek data, see section 2 below.

[5] This setup is also supported by evidence that the distinction between skilled and unskilled people can explain a big part of income inequality at least among "the other 99%" as argued by Autor (2014). See also e.g. Acemoglu (1998), Autor et al (1998), Krusell et al (2000), Hornstein et al (2005), Goldin and Katz (2008), He and Liu (2008), Acemoglu and Autor (2011), Acemoglu (2009, chapter 15), Aghion and Howitt (2009, chapter 8), He (2012) and Angelopoulos et al (2017, 2020). For Greek data, see section 2 below.

natural way. For instance, regarding social policies, public spending on education and health contribute to the accumulation of individual human capital of younger generations, public spending on social protection provides pensions to the old generations, etc. Regarding taxes, we assume that households pay income (capital and labor) taxes as well as social security contributions, while, firms pay corporate taxes and social security contributions. All social security contributions are used to finance a partially funded pay-as-you-go (PAYG) public pension system.

The model is calibrated and solved using annual data from Greece over 2001-2019 and this pre-covid solution serves as a departure to study the effects of several hypothetical permanent changes in public policies. The latter include increases in some items of public spending related to social policy, a reallocation of the existing public spending in favor of the poor-born or the unskilled, changes in tax policy, and finally a switch from a partially funded PAYG public pension system to a fully funded system a la Acemoglu (2009, chapter 9). In all cases, we force the economy to go back to the initial public debt-to-GDP ratio as it was in 2019 so as to make our experiments comparable in terms of fiscal cost.

Our main results are as follows. An increase in public spending on education when provided to both skilled (or rich-born) and unskilled (or poor-born) people, improves the net-of-tax lifetime income of everybody, is good for the aggregate economy and, on top of all this, reduces relative income inequality. An increase in inheritance taxes works similarly. This happens because such policies improve individual incentives, stimulate investments in human and physical capital and also because productive factors are complementary to each other in general equilibrium.

At the other end, there are public policies that, although they reduce relative income inequality, they make everybody worse off and simply the rich-born get more worse off than the poor-born. This is the case of an increase in pensions for everybody, a redistribution of the existing public spending on education in favor of the low-skilled only and a redistribution of the existing public spending on health in favor of the low-skilled only. This happens because higher pensions to the rich discourage aggregate savings and capital accumulation, while lower public spending on the education and health of the high-skilled hurts aggregate productivity and - again because of production complementarities - all this proves to be bad for the low-skilled or the poor-born too.

Finally, there are cases with mixed implications so that political economy issues arise. For example, under the current partially funded PAYG system, a reallocation of the existing public spending on pensions in favor of the low-skilled at the cost of lower pensions to the rich-born is good for the aggregate economy and the poor-born but hurts the rich-born. A switch from the current partially funded PAYG system to a fully funded public pension system improves the net lifetime income of both agents, is good for the aggregate economy but it comes at the cost of higher relative inequality since it is the rich-born who benefit by more.

There are several policy messages from our results. To the extent that inequality is driven by unequal initial conditions, changes in public policies can make things better or worse. The first message is well-known. Incentives to work, save and invest in all types of capital are crucial to both aggregate and individual outcomes. Incentives produce second-round or general equilibrium effects that may move outcomes in the opposite direction from that of first-round effects. Second, in general equilibrium, the public perception that there is always an unpleasant tradeoff between efficiency and equity, or equivalently that growth is regressive, is not correct at least in the medium and long run. Higher public education spending for all and growth-enhancing tax policies like higher inheritance taxes are examples. Third, production complementarities are important. For instance, as said above, an increase in public spending on the education of the poor, to the extent that this is financed by a decrease in public spending on the education of the skilled, is bad for the aggregate economy so everybody becomes worse off even if inequality is reduced in relative terms. Fourth, the policies that have the strongest beneficial effect on both equity and efficiency are those that enhance the human capital of all agents in their young age.[6] Fifth, if there are tradeoffs between aggregate efficiency and inequality, as it happens in the case the economy switches to a fully funded public pension system, it is better to go for the former and complement this with a tax-transfer policy that supports those being hurt.

The rest of the paper is as follows. Section 2 presents data. Section 3 presents and solves the model. Section 4 matches the model to Greek data. Section 5 presents the main results. Section 6 closes the paper. Algebraic details are placed in an Appendix.

2 A look at the data

This section presents some data that are supportive to our model. Tables 1a and 1b are borrowed from OECD (2019). They show data on income inequality and poverty rates respectively across OECD countries. As can be seen, Greece scores rather poorly among European Union countries on both fronts.

Table 1a: Income inequality across OECD countries

Table 1b: Poverty rates across OECD countries

It is also recognized, as said in the opening paragraphs of the Introduction, that in most EU and OECD and countries there is inter-generational transmission of advantages and disadvantages from parents and grandparents to their children (see e.g. OECD (2018) and Eurostat (2021)). This is reflected in the education level, lifetime earnings, poverty, etc. But there are also differences across countries as shown in Tables 1c and 1d borrowed from Eurostat (2021). Table 1c shows the correlation between the risk of poverty of current adults and the financial situation of their parents. Table 1d shows the correlation between the risk of poverty of current adults and the educational level of their parents. Again Greece scores rather poorly on both fronts among European Union countries. Thus, the data reveal an inter-generational persistence in (dis)advantages that inhibits social mobility as embeded into our model.[7]

[6] See also e.g. Cunha and Heckman (2007), Heckman and Mosso (2014), Rubio-Codina et al (2015), Francesconi and Heckman (2016) and Dettmer et al (2020).

[7] Papers on inequality in Greece include Andriopoulou et al (2017) who provide evidence that education accounted for between a fifth and a quarter of inequality in 2007-2014; Cholezas and Tsakloglou (2005) who conclude there is a strong

Table 1c: Risk of poverty of current adults and the financial situation of their parents

Table 1d: Risk of poverty of current adults and the education level of their parents

3 Model

We consider a small open economy populated by households, firms and the government. We start with an informal description of the model.

3.1 Informal description of the model

Regarding households, we distinguish between two types, called rich-born and poor-born. Both types can live for three periods as young, adult and old in an OLG setup.[8] Also, both types devote the first period to education, the second to active economic life and the third to retirement. On the other hand, the two types differ in initial levels of financial and human capital, which both depend on their family background, and these differences in initial conditions shape different lifetime opportunities and choices (see section 2 above). In particular, the rich-born start with an advantage. They inherit a better human capital as well as financial wealth. Hence, when they become adults, they are skilled, which enables them to enjoy a higher wage rate, and participate in domestic and foreign asset markets. Income from these assets, as well as a public pension, make their income when old and this allows them to leave a financial bequest which is inherited by the newly rich-born of the next generation. By contrast, the poor-born inherit a smaller human capital and no financial wealth. Thus, when they become adults, their human capital allows them to work as unskilled workers only, which means a lower wage rate and inability to save. The old member of this poor family lives only of his/her public pension and is not able to leave a financial bequest to the newly poor-born of the next generation.[9] We also assume that there is no mobility between the two groups (see section 2 above). Households are modeled in subsection 3.2.

Regarding firms, given the evidence that skill-biased technological progress is behind the wage premium to skilled workers, and this has been happening despite the concurrent rise in the number of college graduates, we use the technology introduced by Stokey (1996) and Krusell et al (2000) and used by many others since then. Namely, to produce a single traded good, the firm uses physical capital and two types of labor services, skilled and unskilled, where the former is more complementary to capital than unskilled labor; hence the skill premium. Firms are modeled in subsection 3.3.

relationship between education and inequality in Greece, especially, at higher/tertiary education; Missos (2021) who finds that the educational level, and subsequently the professional status of a Greek individual, can explain about 30% of aggregate inequality, with the contribution of other socioeconomic and demographic factors being relatively small; Christopoulou and Monastiriotis (2016) who study the wage premium in the public sector; Papapetrou (2006) who find that the wage premium varied between 25 and 40 per cent in the 1970s and 1980s, reached 50 per cent in the 1990s, and remained high at around 32 per cent in the 2000s; Saez et al (2012) who study the effects of payroll taxes on inequality in Greece.

[8] See e.g. de la Croix and Michel (2002) and Acemoglu (2009) for reviews of OLG models.

[9] Rodriguez-Palenzuela et al (2016) provide evidence that, in the eurozone, wealth is highly concentrated at the top, that savings are generated by only 20% of the households and this is reflected to the distribution of income, and that savings are higher for those with high education level.

Regarding the government, we assume a rich menu of taxes and public spending items as they are recorded in the data. Public spending items will include spending on education, health, pensions, transfer payments and also public infrastructure investment. Taxes will include personal income taxes, corporate taxes, social security contributions, consumption taxes and inheritance taxes. We assume a partially funded pay-as-you-go (PAYG) public pension system according to which the government collects the compulsory social security contributions paid by employees and employers to finance the pensions of the current old. Any differences between revenue and spending in both the general government budget and the social security budget are financed by the issuance of government bonds which can be held by both domestic and foreign agents. The public sector is presented in subsection 3.4.

3.2 Households

Households can live for three periods (as young, adult and old), consume in each period, invest in education when young being supported by their parents, work when adult and retire when old; as pointed out by e.g. De la Croix and Michel (2002, chapter 5), assuming three-period lived households is the simplest way to capture the three main stages of life (education, active economic life and retirement).

3.2.1 Rich-born households

Each rich-born individual is indexed by superscript r. A rich young individual starts with his/her grandparents' bequest and spends effort time and private tuition fees in education. When he/she becomes adult, he/she works as a skilled person and saves in the form of capital, government bonds and foreign assets. When he/she reaches the old age, he/she uses his/her own savings as well as a public pension, and dies with certainty leaving an optimally chosen bequest which will be inherited by the newly rich-born people.

Budget constraints When a person is born rich at time t and remains so in the rest of his/her life, the budget constraints when young, adult and old at t, $t+1$ and $t+2$ respectively are:

$$\left(1+\tau_t^c\right)c_t^{r,y}+z_t^{r,y}=\left(1-\tau_t^b\right)b_{t-1}^{r,y}+\Psi_t^{r,y} \tag{1a}$$

$$\left(1+\tau_{t+1}^c\right)c_{t+1}^{r,m}+k_{t+1}^{r,m}+d_{t+1}^{r,m}+f_{t+1}^{r,m}+\frac{x^f}{2}(\ f_{t+1}^{r,m}-\ f^{r,m})^2+\Psi_{t+1}^{r,m}=\left(1-\tau_{t+1}^n-\tau_{t+1}^s\right)w_{t+1}^r h_{t+1}^{r,m}l_{t+1}^{r,m}+g_{t+1}^{t,r,m} \tag{1b}$$

$$\left(1+\tau_{t+2}^c\right)c_{t+2}^{r,o}+b_{t+2}^{r,o}=\left[1-\delta^k+\left(1-\tau_{t+2}^k\right)r_{t+2}^k\right]k_{t+1}^{r,m}+\left(1-\tau_{t+2}^k\right)\pi_{t+2}^{r,o}+\left(1+r_{t+2}^d\right)d_{t+1}^{r,m}+\left(1+r_{t+2}^*\right)f_{t+1}^{r,m}+s_{t+2}^{r,o} \tag{1c}$$

where $c_t^{r,y}$, $c_{t+1,}^{r,m}$ and $c_{t+2}^{r,o}$ are r's consumption when young, adult and old respectively, $b_{t-1}^{r,y}$ is an endowment inherited from his/her grandparents/old of the previous generation in case a new person is born in a rich family, $\Psi_t^{r,y}$ is a gift or transfer received by a young rich person from his/her parents/adults, $z_t^{r,y}$ is private spending on education when young and rich, $h^{r,m}_{t+1}$ is the stock of human capital of a skilled adult (see below for the motion of human capital), $l^{r,m}_{t+1}$ is work hours of a skilled adult, w^{r}_{t+1} is the wage rate earned by skilled people, $g^{t,r,m}_{t+1}$ is a transfer payment to each rich adult from the government, $k^{r,m}_{t+1}$ is savings in the form of physical capital, $d^{r,m}_{t+1}$ is savings in the form of government bonds, $f^{r,m}_{t+1}$ is savings in the form of foreign assets (or foreign liabilities if it is negative), $\frac{x^f}{2}(f^{r,m}_{t+1} - f^{r,m})^2$ is a resource cost associated with participation in foreign asset markets where $f^{r,m}$ denotes their steady state value, $\Psi^{r,m}_{t+1}$ is a gift or transfer from parents/adults to their children,[10] r^{k}_{t+2}, r^{d}_{t+2} and r^{*}_{t+2} denote respectively the returns to physical capital, government bonds and foreign assets, $\pi^{r,o}_{t+2}$ is dividends received from the ownership of firms, $s^{r,o}_{t+2}$ is the pension provided to each rich old person by the government, and $b^{r,o}_{t+2}$ is a financial bequest to the next cohort of rich people.[11] Finally, $0 \leq \tau^{c}_{t}$, τ^{n}_{t}, τ^{k}_{t}, $\tau^{b}_{t} < 1$ are proportional tax rates on consumption, labor income, personal capital income and financial bequests respectively, while $0 \leq \tau^{s}_{t} < 1$ is a proportional social security contribution paid by employees.[12]

Motion of human capital The human capital of the r household at the beginning of $t+1$ when adult/work life starts is determined by:

$$h^{r,m}_{t+1} = \left(1 - \delta^{r,h}\right) h^{r,y}_{t} + B^{r} \left(e^{r,y}_{t}\right)^{\theta} \left[\gamma \left(z^{r,y}_{t}\right)^{\nu} + (1-\gamma) \left(g^{r,e}_{t} + \kappa g^{r,h}_{t}\right)^{\nu}\right]^{\frac{1-\theta}{\nu}} \tag{2}$$

where $h^{r,y}_{t}$ is r's human capital inherited by his/her predecessors (see Appendix A.1 for the motion of human capital stocks across generations in an r family and so how $h^{r,y}_{t}$ has been determined), $e^{r,y}_{t}$ is r's effort time spent in education when young, $z^{r,y}_{t}$ is private tuition fees spent by a young person born in a rich family, $g^{r,e}_{t}$ and $g^{r,h}_{t}$ are respectively government spending per rich young person allocated to education and health services, the parameter $0 \leq \kappa \leq 1$ measures how much public spending on health contributes to the quality of human capital (unhealthy people cannot be efficient, irrespectively of their education level), and $B^{r} > 0$, $0 \leq \theta \leq 1$, $0 \leq \gamma \leq 1$, $0 \leq \nu \leq 1$ are parameters.[13] In other words, private tuition fees and public policies are combined into a composite via a CES technology, with an elasticity of substitution $\frac{1}{1-\nu}$ and relative importance γ, and then this composite combines with effort, $e^{r,y}_{t}$, via a Cobb-Douglas technology, with a

[10] $\Psi^{r,m}_{t+1}$ and $\Psi^{r,y}_{t}$ are linked to each other (see the market-clearing conditions in Appendix C).

[11] $b^{r,o}_{t+2}$ and $b^{r,y}_{t-1}$ are linked to each other (see the market-clearing conditions in Appendix C).

[12] This modelling is as in e.g. Bruce and Turnovsky (2013). Alternatively, we could assume that the labor income tax, τ^{n}_{t}, is imposed after we deduct social security contributions. We report that our main results do not depend on the particular way we model this.

[13] That is, individual human capital can be augmented by both private resources and public policy (see also e.g. Glomm and Ravikumar (1992), Kaganovich and Zilcha (1999), Blankenau and Simpson (2004), Blankenau (2005) and Arcalean and Schiopu (2010)). More specifically, as pointed out by De la Croix and Michel (2002, chapter 5), there are three ways of accumulating human capital. First, the individual decision on the length/effort of education. Second, public spending on education. Third, individual spending on education, where the latter can be financed in various ways like parental funding and/or borrowing from the credit market. In our paper we do not include a credit market, although we report that our results are not sensitive to this to the extent that the credit market is imperfect in the sense that the poor or unskilled can borrow at an extra cost (for credit market imperfections as well as borrowing and lending that allows poor households to finance human capital accumulation and climb up the income ladder, see e.g. Galor and Zeira (1993), Acemoglu (2009, chapter 21.6) and Quadrini and Rios-Rull (2014)).

relative share θ for $e_t^{r,y}$.[14] The resulting end-of-period stock, $h_{t+1}^{r,m}$, is used by the adult during his/her work life at $t+1$ (see equation 1b above).

Utility function The discounted lifetime utility of a person who is born rich at time t and remains rich for the rest of his/her life is:

$$u_t^r = \frac{(c_t^{r,y})^{1-\sigma}}{1-\sigma} - \chi_n \frac{(e_t^{r,y})^{1+\eta}}{1+\eta} + \chi_g \frac{(g_t^u)^{1-\eta_g}}{1-\eta_g} +$$

$$+\beta \left\{ \frac{(c_{t+1}^{r,m})^{1-\sigma}}{1-\sigma} - \chi_n \frac{(l_{t+1}^{r,m})^{1+\eta}}{1+\eta} + \chi_g \frac{(g_{t+1}^u)^{1-\eta_g}}{1-\eta_g} \right\}$$

$$+\beta^2 \left\{ \frac{(c_{t+2}^{r,o})^{1-\sigma}}{1-\sigma} + \chi_g \frac{(g_{t+2}^u)^{1-\eta_g}}{1-\eta_g} + \beta \chi_b \frac{(b_{t+2}^{r,o})^{1-\eta_b}}{1-\eta_b} \right\} \tag{3}$$

where, as said above, $c_t^{r,y}$, $c_{t+1,}^{r,m}$ and $c_{t+2}^{r,o}$ are r's consumption when young, adult and old respectively, $e_t^{r,y}$ is effort time spent in education when young, $l_{t+1}^{r,m}$ is effort time spent in work when adult and $b_{t+2}^{r,o}$ is the bequest chosen by the old.[15] Also, g_t^u denotes per capita public spending on "utility-enhancing" public goods and services (see below for their definition), while, the parameter $0 < \beta < 1$ is the subjective time preference rate and σ, χ_n, η, χ_g, η_g, χ_b, η_b are preference parameters.

The first-order conditions for $e_t^{r,y}$, $z_t^{r,y}$, $l_{t+1}^{r,m}$, $k_{t+1}^{r,m}$, $d_{t+1}^{r,m}$, $\Psi_{t+1}^{r,m}$ and $b_{t+2}^{r,o}$ are in Appendix A.1.

3.2.2 Poor-born households

Each poor-born individual is indexed by superscript p. Differently from a rich-born person, a poor young individual starts without inherited financial capital and with relatively little (i.e. unskilled-type) human capital. He/she can accumulate human capital but, when he/she becomes adult, he/she works as as unskilled person and does not save. So, when he/she reaches the old age, he/she lives on a public pension and dies without leaving a financial bequest to the next generation.

Budget constraints When a person is born poor at time t and remains so for the rest of his/her life, the budget constraints when young, adult and old at t, $t+1$ and $t+2$ respectively are:

$$(1+\tau_t^c)\, c_t^{p,y} = \Psi_t^{p,y} \tag{4a}$$

[14] This functional form can nest several cases in the literature; see e.g. De la Croix and Michel (2002, chapter 5), Blankenau and Simpson (2004), Blankenau (2005) and Arcalean and Schiopu (2010). See Attanasio et al (2020) for estimation of human capital production functions.

[15] The way we model the bequest motive follows e.g. Acemoglu (2009, chapter 9) and Coeurdacier et al (2015)

$$\left(1+\tau_t^c\right)c_{t+1}^{p,m}+\Psi_{t+1}^{p,m}=\left(1-\tau_{t+1}^n-\tau_{t+1}^s\right)w_{t+1}^p h_{t+1}^{p,m} l_{t+1}^{p,m}+g_{t+1}^{t,p,m} \tag{4b}$$

$$\left(1+\tau_{t+2}^c\right)c_{t+2}^{p,o}=s_{t+2}^{p,o} \tag{4c}$$

where variables are as defined above in the rich person's problem if we replace the superscript r with the superscript p.[16]

Motion of human capital The human capital of the p household at the beginning of $t+1$ when adult/work life starts is:

$$h_{t+1}^{p,m}=\left(1-\delta^{p,h}\right)h_t^{p,y}+B^p\left(e_t^{p,y}\right)^{\theta}\left[(1-\gamma)\left(g_t^{p,e}+\kappa g_t^{p,h}\right)^{\nu}\right]^{\frac{1-\theta}{\nu}} \tag{5}$$

where variables are as defined above if we replace the superscript r with the superscript p (see Appendix A.2 for the motion of human capital stocks across generations in a p family and so how $h_t^{p,y}$ has been determined). As said above, we assume that the poor-born people cannot afford private tuition fees.[17]

Utility function The discounted lifetime utility of a person who is born poor at time t and remains poor in the rest of his/her life is:

$$u_t^p=\frac{(c_t^{p,y})^{1-\sigma}}{1-\sigma}-\chi_n\frac{(e_t^{p,y})^{1+\eta}}{1+\eta}+\chi_g\frac{(g_t^u)^{1-\eta_g}}{1-\eta_g}+$$

$$+\beta\left\{\frac{(c_{t+1}^{p,m})^{1-\sigma}}{1-\sigma}-\chi_n\frac{(l_{t+1}^{p,m})^{1+\eta}}{1+\eta}+\chi_g\frac{(g_{t+1}^u)^{1-\eta_g}}{1-\eta_g}\right\}$$

$$+\beta^2\left\{\frac{(c_{t+2}^{p,o})^{1-\sigma}}{1-\sigma}+\chi_g\frac{(g_{t+2}^u)^{1-\eta_g}}{1-\eta_g}\right\} \tag{6}$$

where the only difference from the rich person's utility function is that now there are no financial bequests.

The first-order conditions for $e_t^{p,y}$, $l_{t+1}^{p,m}$ and $\Psi_{t+1}^{p,m}$ are in Appendix A.2.

[16] We do not allow for a separate government transfer to the poor young ($g_t^{t,p,y}$) simply because in practice it is the parents who receive a child benefit. This is not important in our model.

[17] We report that our main results do not change if we also allow for parental funding of tuition fees in the case of the poor born to the extent that poor parents can spend less than rich parents on their children education. Also, as already said above, our main results do not change if we allow the poor born to borrow from a credit market to finance their human capital accumulation to the extent that this credit market is imperfect.

3.3 Firms

There are $f = 1, 2, ..., N_t^f$ firms. Each firm chooses capital and the two labor inputs, denoted as k_t^f, $l_t^{r,f}$ and $l_t^{p,f}$, to maximize net profits given by:

$$\pi_t^f \equiv y_t^f - (1+\tau_t^w)(w_t^r l_t^{r,f} + w_t^p l_t^{p,f}) - r_t^k k_t^f - \tau_t^f (y_t^f - w_t^r l_t^{r,f} - w_t^p l_t^{p,f}) \tag{7}$$

where y_t^f is the firm's output, τ_t^w is the social security contribution paid by employers and τ_t^f is a tax rate on the firm's gross profit, where the latter is defined as sales minus wage payments.

Following e.g. Stokey (1996), Krusell et al (2000), Acemoglu (2009, chapter 15), He (2012) and Angelopoulos et al (2017), the production function is:

$$y_t^f = A\left(\lambda(A^u l_t^{p,f})^\alpha + (1-\lambda)[\mu(A^k k_t^f)^\psi + (1-\mu)(A^s l_t^{r,f})^\psi]^{\frac{\alpha}{\psi}}\right)^{\frac{1-\varepsilon}{\alpha}} \left(\frac{K_t^g}{N_t^f}\right)^\varepsilon \tag{8}$$

where capital, k_t^f, and skilled labor, $l_t^{r,f}$, are combined into a composite CES technology, so that $0 < \mu < 1$ is the importance of capital vis-a-vis skilled labor and $\frac{1}{1-\psi}$ measures the elasticity of substitution between these two factors, $0 < \lambda < 1$ is the importance of unskilled labor, $l_t^{p,f}$, relative to the composite of capital-skilled labor, $\frac{1}{1-a}$ measures the elasticity of substitution between unskilled labor and the composite of capital-skilled labor where $0 < \psi < \alpha < 1$, and the coefficient $0 \leq \varepsilon < 1$ is a measure of the contribution of public infrastructure in production. Finally, A^k, A^s and A^u are separate productivity terms as in Acemoglu (2009, pp. 501-2); these parameters can allow us to study the effects of capital-augmenting technological change as captured by the relative size of A^k. As is well-known, this production function captures the idea that skilled labor is relatively more complementary to capital than unskilled labor, so that any technological progress that favors capital accumulation is more beneficial to skilled labor. At the same time, production exhibits CRS with respect to all inputs.

The firm's first-order conditions are in Appendix B.

3.4 Government

3.4.1 Policy instruments

On the revenue side, the government uses personal capital income taxes, τ_t^k, labor income taxes, τ_t^n, consumption taxes, τ_t^c, corporate income taxes paid by firms, τ_t^f, social security contributions paid by employees and employers, τ_t^s and τ_t^w respectively, as well as inheritance taxes on financial bequests, τ_t^b. There can also be government revenues from the issuance of bonds, where d_t denotes the end-of-period total stock of one-period maturity bonds issued by the government; the latter can be held by both domestic and foreign agents as is the case in the Greek data (see below for details).

On the expenditure side, we have public spending on education, G_t^e, health, G_t^h, pensions, G_t^s, transfer payments, G_t^t, infrastructure, G_t^i, and utility-enhancing activities, G_t^c (see below in the empirical part for the categories included in G_t^c). Equivalently, if these spending items are expressed as shares of GDP, we have $s_t^{g^e}$, $s_t^{g^h}$, $s_t^{g^s}$, $s_t^{g^t}$, $s_t^{g^i}$ and $s_t^{g^c}$. Recall that each one of these spending items plays a distinct role in our model.

All the above fiscal policy instruments can affect different types of agents differently even if they are common. In our model, this happens because the same policy or the same shock affects differently the rich and the poor. But we will also allow for targeted or redistributive policies that target one group at the expense of the other ex ante. In particular, we will allow those items of public spending that do not have a clear public good feature to be allocated in favor of the poor. To do so, we assume that each of G_t^j, where $j = e, h, s, t$ can be divided into two parts, $\zeta_t^j G_t^j$ and $(1 - \zeta_t^j)G_t^j$, where the former is earmarked for the rich and the latter is earmarked for the poor, so that the fraction ζ_t^j is a measure of targeted or redistributive policies. If $\zeta_t^j = n_t^r$ so that $(1 - \zeta_t^j) = n_t^p$, the use of G_t^j is neutral ex ante in the sense that it is allocated according to population shares or, in simple words, all agents receive the same amount of G_t^j. If, on the other hand, $\zeta_t^j < n_t^r$ so that $(1 - \zeta_t^j) > n_t^p$, it is the poor that get the lion's share of G_t^j. This modelling will enable us to study the implications of both non-targeted and targeted public policies. It will also enable us to examine whether some popular policies that look redistributive at first sight are actually so once general equilibrium effects have been taken into account. Thus, we add the fractions of public spending on education, health, pensions and transfers that go to the rich, ζ_t^e, ζ_t^h, ζ_t^s, ζ_t^t, to the menu of public policy instruments.

3.4.2 Government budget constraints

The above policy instruments are linked to each other via budget identities. Under a fully funded PAYG system, which means that the social security system is self-financed via adjustments in one of the two social security contributions (τ_t^s or τ_t^w), we would have two separate budget constraints, one for the general budget and one for the social security system, which would be respectively (in per capita terms):

$$[s_t^{g^h} + s_t^{g^e} + s_t^{g^t} + s_t^{g^i} + s_t^{g^c}]n_t^f y_t^f + \left(1 + r_t^d\right)\left(\lambda_{t-1}^d + \lambda_{t-1}^f\right)\frac{N_{t-1}}{N_t}d_{t-1} + \left(1 + r_t^{eu}\right)\lambda_{t-1}^{eu}\frac{N_{t-1}}{N_t}d_{t-1} = d_t + \frac{T_t}{N_t} \quad (9)$$

$$s_t^{g^s} n_t^f y_t^f = \tau_t^s[n_t^{r,m} w_t^r l_t^{r,m} h_t^{r,m} + n_t^{p,m} w_t^p l_t^{p,m} h_t^{p,m}] + \tau_t^w n_t^f (w_t^r l_t^{r,f} + w_t^p l_t^{p,f}) \quad (10)$$

which would determine the end-of-period total public debt expressed in per capita terms, d_t, and one of the two social security tax rates, τ_t^s or τ_t^s. Notice that $0 \leq \lambda_t^d,\ \lambda_t^f,\ \lambda_t^{eu} < 1$, where $\lambda_t^d + \lambda_t^f + \lambda_t^{eu} = 1$ at each t, denote respectively the fractions of total Greek public debt held by domestic private agents, foreign private agents and non-market EU institutions (like ESM, the ECB, etc); see e.g. Economides et al (2021) for details and data. In a small open economy model, $0 \leq \lambda_t^f, \lambda_t^{eu} < 1$ are set as in the data so that $\lambda_t^d = 1 - \lambda_t^f - \lambda_t^{eu}$. Also, in equilibrium, $\lambda_t^d d_t = n_t^{r,m} d_t^{r,m}$. Also notice that while r_t^d is endogenously determined, the interest rate when the country borrows from non-market EU institutions, r_t^{eu}, is set exogenously being a policy rate.

By contrast, under a partially funded PAYG system in which the social security system is not self-financed, as is the case in Greece, we have a consolidated budget constraint:

$$[s_t^{g^h} + s_t^{g^e} + s_t^{g^t} + s_t^{g^i} + s_t^{g^c}] n_t^f y_t^f + \left(1 + r_t^d\right) \left(\lambda_{t-1}^d + \lambda_{t-1}^f\right) \frac{N_{t-1}}{N_t} d_{t-1} + \left(1 + r_t^{eu}\right) \lambda_{t-1}^{eu} \frac{N_{t-1}}{N_t} d_{t-1} +$$

$$+ s_t^{g^s} n_t^f y_t^f - \tau_t^s (n_t^{r,m} w_t^r l_t^{r,m} h_t^{r,m} + n_t^{p,m} w_t^p l_t^{p,m} h_t^{p,m}) - \tau_t^w n_t^f (w_t^r l_t^{r,f} + w_t^p l_t^{p,f}) == d_t + \frac{T_t}{N_t} \tag{11}$$

so that now we can move both τ_t^s and τ_t^w to the list of exogenous set variables and the single budget constraint determines d_t.

The tax revenues are (in per capita terms):

$$\frac{T_t}{N_t} \equiv \tau_t^c (n_t^{r,y} c_t^{r,y} + n_t^{r,m} c_t^{r,m} + n_t^{r,o} c_t^{r,o} + n_t^{p,y} c_t^{p,y} + n_t^{p,m} c_t^{p,m} + n_t^{p,o} c_t^{p,o}) +$$

$$+ \tau_t^n (n_t^{r,m} w_t^r l_t^{r,m} h_t^{r,m} + n_t^{p,m} w_t^p l_t^{p,m} h_t^{p,m}) + \tau_t^k \frac{N_{t-1}}{N_t} n_{t-1}^{r,m} (r_t k_{t-1}^{r,m} + \pi_t^{r,o}) +$$

$$+ \tau_t^b n_t^{r,y} b_{t-1}^{r,y} + \tau_t^f n_t^f \left(y_t^f - w_t^r l_t^{r,f} - w_t^p l_t^{p,f}\right) \tag{12}$$

Finally, the law of motion for public capital is (in per capita terms):

$$\frac{N_{t+1}}{N_t} k_{t+1}^g = (1 - \delta^g) k_t^g + s_t^{g^i} n_t^f y_t^f \tag{13}$$

3.5 Macroeconomic system

Collecting all equations, the equilibrium macroeconomic system is presented in detail in Appendix C. It consists of 51 equations in 51 variables. This is given the exogenously set policy instruments and initial conditions for the state variables. The latter include the 6 population shares and the 6 human capital stocks of the three age groups for each of the two social groups, the stocks of private and public physical capital, the stock of public debt, the stock of foreign assets/liabilities held by private agents, and the stock of financial bequests inherited by the newly-born rich.

3.6 Solution steps and methodology

In what follows, we will work as follows. We will first present parameter values and pre-covid data from Greece. Then, using them, we will get a steady state solution of the model; this solution can be thought of as the trend of the Greek economy before the pandemic shock. In turn, using this initial steady state solution as a point of departure, we will simulate the transition path to a new steady state when dynamics are driven by permanent reforms in public policy variables. For the solutions, we will use a Newton-type non-linear method implemented in DYNARE. Since the model is kept deterministic, transition dynamics will be driven by policy reforms only.

4 Parameters and data used in the solutions

The model is calibrated and solved using Greek data. Subsection 4.1 presents parameter values calibrated to annual pre-covid data of the Greek economy over 2001-2019. Subsection 4.2 presents Greek data for policy variables in the year 2019 which was the last year before the eruption of the pandemic. Finally, based on subsections 4.1 and 4.2, subsection 4.3 reports the resulting steady state solution which will serve as a departure for our policy experiments in the next sections.

4.1 Parameter values

Regarding parameters, we use conventional values for some of them and set the rest so as the model's steady state solution is consistent with data averages over 2001-2019. Baseline parameter values are listed in Table 2a. Before we discuss these values, we report that our main results are robust to changes in these values at least within reasonable ranges.

Utility function The time unit is meant to be a period consisting of 25 years. The time preference rate, β, is set at 0.985^{25} so as to be consistent with a value for the real annual interest rate around 2.2%. The weight given to utility-enhancing public goods/services, χ_g, and the associated exponent, η_g, are set at 0.1 and 1 respectively as in the similar specification of e.g. Baier and Glomm (2001). The elasticity of intertemporal substitution, σ, is set at 1. The preference parameter related to effort time, χ_n, and the inverse of the Frisch labor supply elasticity, η, are set at 12 and 1 respectively which give work hours within data ranges. Regarding bequests, the weight given to them, χ_b, and the associated exponent, η_b, are set at 5 and 1 respectively so as to get bequests as share of output around 15% (see e.g. Alvaredo et al (2017)).

Production technology Regarding the goods production function, the TFP parameter, A, is set at 1.

The substitutability parameters, ψ and α, are set at -0.49 and 0.3 based on Krusell et al (2000) implying elasticities of substitution between capital and skilled labor and between the composite of capital-skilled labor and unskilled labor about 0.67 and 1.43 respectively. The parameters μ (namely, the importance of capital vis-a-vis skilled labor) and λ (namely, the importance of unskilled labour vis-a-vis the composite of capital-skilled labor) are set at 0.28 and 0.3 respectively, so that the skill premium and the share of skilled workers are close to data averages. The coefficient on public capital, ε, is set at 0.02 which is close to the public investment to GDP ratio in the data as is usual practice (see e.g. Baxter and King (1993)). The separate productivity coefficients, A^k, A^s and A^u, are all set at 1. Finally, as is usual in the OLG literature (see e.g. Heer (2019)), we assume full depreciation of physical and public capital so that δ^k and δ^g are equal to 1 (our results are not sensitive to this).

Human capital technology In the human capital production function, the values of B^r, B^p and θ are set at 10, 8 and 0.75 respectively; these values imply hours of education within usual ranges and, in particular, give $e^{r,y} = 0.22$ and $e^{p,y} = 0.21$ for the skilled and unskilled respectively. Following e.g. Stokey (1996), the parameter, ν, is set at 0.5 (this implies an elasticity of $1/(1-\nu) = 2$) so that private and public education spending are good substitutes. The importance given to private vis-a-vis public spending in the same function, γ, is set at 0.25; this implies that private education spending as share of GDP is around 0.3% which is as in the data. As regards the parameter κ, which measures the contribution of public spending on health relative to public spending on education in the creation of new human capital, we set it at the relatively neutral value of 0.5. Finally, we set the value of the depreciation rates of human capital, $\delta^{r,h}$ and $\delta^{p,h}$, at 0.3. This value corresponds to 0.8% annual depreciation rate which falls within the values reported in Browning et al (1999), Arrazola and de Hevia (2004) and Ludwig et al (2012).

Population The birth and death rates of the two social groups, as specified in Appendix A.3, are set at $\delta_r = 0.03$, $\delta_p = 0.03$, $\nu_r = 0.003$, $\nu_p = 0.01$. These values give population shares close to the data and an average population growth rate of 0.8%.

Table 2a: Baseline parameter values

4.2 Policy variables

Public spending For public spending items, we make use of the disaggregation of the international Classification of the Functions of Government (COFOG) in the framework of the European System of National Accounts (ESA-2010), which is comprised of functional categories of public expenditures. To solve our model, we need data on public spending on education, health, pensions (the latter is the main sub-category of social protection expenditure in the data), transfer payments and infrastructure (infrastructure spending is part of spending on economic affairs in the data). In turn, using data on total public spending, the rest is treated as utility-enhancing spending, s^{g^c}. The values of these public spending items as shares of GDP (s^{g^e}, s^{g^h}, s^{g^s}, s^{g^t}, s^{g^i}) in 2019 are reported in Table 2b. For data completeness, Table 2c reports the functional structure of public spending in Greece in 2019, while Tables 2d and 2e, both borrowed from OECD (2019), show respectively public social spending as share of GDP and the decomposition of it across OECD countries. As can be seen, Greece has a relatively high public social spending share and most of it (differently from all other countries) goes to public pensions, s^{g^s}.

Tax rates The tax rates on consumption, labor income, personal capital income and firms' profits (τ^c, τ^n, τ^k and τ^f) are the average values of the effective tax rates in Greece (the source is European Commission (2018) or have been constructed by us applying the Mendoza-Razin-Tesar methodology and using Eurostat data). Recall that τ^n does not include social security contributions, τ_t^s and τ_t^w, paid by employees and employers respectively; that is, the total tax rate on labor is $\tau^n + \tau_t^s + \tau_t^w$.[18] The value of the inheritance tax rate, τ^b, is set so as to generate inheritance tax revenues of 1% of total tax revenues as in most OECD countries (this implies a value of 0.05).[19] The values of tax rates in 2019 are included in Table 2b. Again for completeness, Table 2f reports the structure of tax revenues in Greece in 2019.

Allocation of public spending We need to decide how those items of public spending that have to do with social policy (education, health, pensions and transfers) are allocated between the two economic groups, skilled and unskilled or equivalently the rich and the poor. Since there are no data on this, in our baseline solutions, we will assume that these spending items are allocated equally, namely, according to the population fractions of the two groups so that we set $\zeta_t^e = \zeta_t^h = \zeta_t^w = \zeta_t^s = \zeta_t^t = n_t^r$ and thus $1 - \zeta_t^e = 1- \zeta_t^h = 1- \zeta_t^s = 1 - \zeta_t^t = n_t^p$. By contrast, when we study targeted redistributive policies, we will assume that the unskilled/poor get the lion's share, namely, they get more than their population fraction, so that we set $\zeta_t^e = \zeta_t^h = \zeta_t^s = \zeta_t^t \to 0$.

Public debt The fractions of Greek public debt in the hands of foreign private banks/agents and EU public institutions, λ^f and λ^{eu}, are set at 0.15 and 0.7 respectively as in calculated by Dimakopoulou et al (2021).

World interest rates In our small open economy model, we set $r^* = 1.22\%$ and $r^{eu} = 1\%$ for the market interest rate on foreign assets and the non-market interest rate on loans received from EU public institutions respectively.

Table 2b: Policy variables used in the solution for 2019

Table 2c: Structure of public spending in 2019

Table 2d: Public social spending across OECD countries

Table 2e: Categories of public social spending across OECD countries

Table 2f: Structure of tax revenues in 2019

[18] In the model above, the value of 0.13 for τ^n does not include the social security contributions, τ_t^w and τ_t^s, paid by employers and employees respectively. Using data average values for τ_t^w and τ_t^s (0.13 and 0.13 respectively over 2001-19), the implied total tax burden on labor income, $\tau^n + \tau_t^s + \tau_t^s$, is 0.39 which is close to its data average value.

[19] See OECD (2021). Inheritance taxes as well as inheritance tax exemption thresholds vary widely across countries.

4.3 Initial steady state solution

Using the parameters in Table 2a and the policy variables in Table 2b, we now solve the model. The steady state solution is presented in Table 3. As can be seen, the solution makes economic sense and the GDP ratios of the key macro variables can mimic reasonably well their values in the data so this solution can serve as a reasonable departure point for our policy experiments below.

Table 3: Initial steady state solution (status quo)

Before we proceed, it is worth clarifying the following. First, in all experiments, the reference will be the status quo solution in Table 3, namely, what would have happened if the policy variables had remained for ever as in the data in the year 2019 at the time of departure. Second, in what follows, we will assume that any exogenous change in policy instruments, etc, is permanent so we will end up at a new steady state. Third, in all cases studied, the residually determined variable that closes the consolidated government budget identity will be the end-of-period public debt.

5 Public policy reforms and their effects

Within the above economic environment, we now investigate the aggregate and distributional implications of various public policies. We will first define the policies studied (subsection 5.1) and then embed them into our model to quantify their implications (subsections 5.2 and 5.3).

5.1 Policy scenaria studied

As said, we assume that the economy is at its initial steady state (its status quo) at time 0 and then there are permanent changes in public policy. We will distinguish four kinds of policy changes or reforms. The first assumes permanent increases in some categories of social spending. The second redistributes the same categories in favor of the poor. The third studies permanent changes in tax policy. Fourth, we study a permanent change in the public pension system.

The reforms studied are listed in Table 4. We realize of course that this list is selective. We report however that we have also experimented with changes in other categories of public spending and/or taxes (availabe upon request), but here we choose to focus on policies that that are at the heart of policy debates on inequality and redistribution.

Table 4: List of policy reforms studied

In the first type of experiments, R1-R3, we start with 1 percentage point (pp) permanent increases in public spending on education, health and pensions, all expressed as shares of GDP ($s_t^{g^e}$, $s_t^{g^h}$, $s_t^{g^s}$). In this first type of experiments, spending increases are assumed to be population-wide or non-targeted in the sense that each spending item is allocated to the two social groups (rich-born and poor-born) according to their fractions in population (i.e. $\zeta_t^e = \zeta_t^h = \zeta_t^s = n_t^r$). In other words, as said above, both types of agents receive the same amount, although of course the same policy, or the same amount of public spending, can affect different agents differently because of their heterogeneity (for instance, agents differ in initial conditions).

In the second type of policy experiments, R4-R6, we keep total public spending as well as each of its items as in the status quo solution, but we now assume that they target the poor in the sense that now the poor get a share of the existing public spending that exceeds their fraction in population (i.e. $\zeta_t^e = \zeta_t^h = \zeta_t^s \rightarrow 0 < n_t^r$ or equivalently $1 - \zeta_t^e = 1 - \zeta_t^h = 1 - \zeta_t^s \rightarrow 1 > n_t^p$).

In the third type of policy experiments, R7, we study the effects of an increase in the inheritance tax rare, τ^b. In particular, we assume an increase in τ^b such that the associated tax revenue as share of GDP increases by 1 pp again. Note that we present results for inheritance taxes only because one's initial conditions play a key role in our model.

In the fourth type of policy experiments, R8, we will assume that the partially funded PAYG public pension system assumed so far is replaced by a fully funded system in which the government collects the compulsory social security contributions of all working adults, invests them in the only productive asset in the model (capital), receives the return on its investment and finally uses the resulting capital and its return to pay back the same people in their old age (this is as in e.g. Acemoglu (2009, chapter 9.5)). This new public pension system is modeled in Appendix D.

To understand the logic of our results, and following usual practice in the literature, we will study one policy change at a time. However, before we present any of these cases, we have to address the issue of public debt sustainability.

5.2 Debt sustainability along the transition

We report that when we depart from the initial steady solution in 2019 (see section 3) and feed the model with any policy changes like those described above, the model does not exhibit dynamic stability so that no equilibrium path exists. This happens because the trajectory for public debt is explosive over time. Some kind of fiscal policy adjustment is necessary at some point in time to stabilize the public debt and make the current situation sustainable. It should be pointed out that this is not an unusual problem (see e.g. Davig et al (2010) and Malley and Philippopoulos (2022) for the US economy, and Dimakopoulou et al (2021) for the Greek economy).[20]

To restore dynamic stability, following most of the related literature (for a review, see e.g. D' Erasmo et al (2015)), we assume that a policy instrument reacts systematically to deviations of public debt from a

[20] This is equivalent to saying that the real interest rate on government bonds is higher than the economy's growth rate so that the government cannot roll over its debt and hence there is need for a cut in spending, a rise in tax rates, etc, at some time in the future. This is the case in the Greek data: during 2001-2019, the average real interest rate on 10-year government bonds was 5.89% and the average growth rate was 0.15%. On the other hand, see Blanchard (2019) for the 2010s where the real interest rates were lower than the growth rates at least in the US economy thanks to the unconventional quantitative monetary policies of the FED.

target. In particular, we propose that, during the transition from the initial steady state to the new steady state, the tax rate on labor income, τ^n, adjusts following the feedback policy rule:

$$\tau_t^n = \rho^n \tau_{t-1}^n + (1-\rho^n)\,\tau^n + \gamma^n \left(\frac{d_t}{y_t} - \frac{d}{y}\right) \tag{14}$$

where τ^n is the value of the tax rate in the new steady state, $0 \leq \rho^n \leq 1$ is a persistence parameter, $\frac{d}{y}$ is the target value of the debt to GDP ratio which is assumed to be that of the initial steady state for reasons of public financing comparability across policy regimes, and $\gamma^n \geqq 0$ is a feedback policy coefficient. In our solutions, we will set $\rho^n = 0.95$ and $\gamma^n = 0.2$; this value of γ^n is the lowest possible value that allows us to get a non-explosive transition path under all policy scenaria studied. In other words, during the transition, policy changes are financed by a mix of changes in the end-of-period public debt and changes in the labor tax rate that needs to respond to changes in public debt over time.

5.3 Main results

Table 5 reports steady state solutions under all cases (impulse response functions, when we travel from the initial steady state to the reformed ones, are also available upon request). That is, this table reports steady state solutions for the key endogenous variables when we feed the model with the eight permanent policy changes, R1-R8, while, the first column repeats the solution of the initial steady state in section 3 which serves as a benchmark.

In particular, columns R1-R3 report the new steady solution when there is a permanent increase in public spending on education, health and pensions ($s_t^{g^e}$, $s_t^{g^h}$, $s_t^{g^s}$) provided equally to everybody; columns R4-R6 illustrate what happens when there is a permanent reallocation of the existing public spending on these three categories ($s_t^{g^e}$, $s_t^{g^h}$, $s_t^{g^s}$) in favor of the poor-born only; column R7 shows what happens in the new steady state when there is a permanent rise in the inheritance tax rate as defined above; finally, column R8 shows the steady state effects of a switch from a partially funded PAYG system to a fully funded public pension system again as defined above.

The key endogenous variables included in Table 5 are the economy's GDP (y^f), the economy's capital stock (k^f), the net-of-taxes income of the two social groups during their young, adult and old lifes ($y^{r,net}$ and $y^{p,net}$), as well as their ratio, ($y^{r,net}/y^{p,net}$) which is used as a measure of inequality, the human capital of the two groups in their adult working lifes ($h^{r,m}$ and $h^{p,m}$), the levels of consumption of both agents and in all three stages of their lifes ($c^{r,y}$, $c^{r,m}$, $c^{r,o}$ for the rich and $c^{p,y}$, $c^{p,m}$, $c^{p,o}$ for the poor), the pension received by each agent when old ($s^{r,o}$ and $s^{p,o}$) and finally in the last row the debt-to-GDP ratio at steady state which, thanks to the definition of the debt gap in the feedback policy rule used, is the same across experiments and equal to that in the initial steady state for reasons of fiscal comparability across regimes.

Table 5: Steady state solutions

Inspection of Table 5 implies the following. The majority of the policy changes studied manage to reduce net income inequality, $y^{net,r}/y^{net,p}$. Actually, this happens in all cases except R8 which is the case of the reform in the public pension system. However, as can be seen, a reduction in the net income ratio, $y^{net,r}/y^{net,p}$, is not always translated in better opportunities and higher net incomes for the poor-born in absolute terms; in some cases, it just means that everybody gets worse off and simply the rich-born get more worse off than the others. This is especially so in the case of a general increase in pensions for everybody (R3), a redistribution of the existing public spending on education in favor of the low-skilled only (R4) and a redistribution of the existing public spending on health in favor of the low-skilled only (R5). In these three cases, everybody is eventually hurt in general equilibrium, just the high-skilled are being hurt more. The macroeconomy is also worse off (see y^f). All this is explained by detrimental general equilibrium effects that work through individual incentives, factor prices and production complementarities. In particular, higher pensions to the rich discourage aggregate savings and capital accumulation (see k^f). Lower public spending on the education and health of the high-skilled hurts aggregate productivity and this proves to be bad for the low-skilled too.

At the other end, there are public policies that are Pareto-improving, in the sense that they improve the net lifetime income of both skilled and unskilled, are growth-enhancing at macroeconomic level, and, on top of all this, reduce inequality at least after the early periods. This win-win scenario can happen in the case of an increase in public spending on education when provided to all members of the society (R1) and in the case of higher inheritance taxes (R7). In the case of R1, this happens because a general increase in public education spending enhances the accumulation of human capital of all agents. In turn, physical capital accumulation also increases since human and physical capital are complementary in production. This proves to be good for everybody and, as our measure on inequality, $y^{net,r}/y^{net,p}$, shows, especially for the low-skilled. In the case of R7, a rise in inheritance taxes forces the high-skilled to invest more in human and physical capital during their lifetime and this is good not only for the aggregate economy but also for personal net incomes as well as for equality (see the fall in $y^{net,r}/y^{net,p}$ under R7).

There are also cases in between, meaning with mixed implications, where political economy issues arise and so social judgements need to be made. For example, there are mixed effects under R6, namely, the case of a reallocation of the existing public spending on pensions in favor of the low-skilled at the cost of lower pensions to the rich-born. This is driven by both demand and supply effects. In particular, thanks to higher pensions, the poor born can consume more and this increases aggregate demand. At the same time, a cut in pensions pushes the rich to save more and this is good for capital accumulation and hence for aggregate supply. As a result of all this, the aggregate economy and the poor-born benefit, while the rich born are worse off. There are also mixed effects from R2, namely an increase in public spending on health for everybody. In these solutions, R2 enhances the accumulation of physical and human capital and this is good for the aggregate economy as well as for income equality, but the net incomes of both agents decrease because of the increase in labor taxes that have to respond to rising public debt over time.[21] Finally, R8, namely the reform of the public pension system, is Pareto-improving in the sense that it improves the net lifetime income of both agents, enhances the accumulation of both human and physical capital and is growth-enhancing at macroeconomic level, but this comes at the cost of higher inequality. It is worth noticing here that R8 results in higher pensions for both agents thanks to a switch to a more efficient economy.

It is important to note here that when a reform creates winners and losers on its own but nevertheless is beneficial to the aggregate economy - as it happens for instance under R6, R2 and especially under the public pension reform in R8 - this can be transformed into a Pareto-improving reform combined with lower relative inequality if it is supplemented with a well-designed tax-transfer policy scheme that supports those who lose from a higher aggregate pie. But, as said, we prefer to focus on one policy change at a time to make results clearer.

6 Closing the paper

In this paper, we evaluated the aggregate and distributional implications of a rich range of public policies typically used to combat inequality in a general equilibrium OLG model parameterized to the Greek economy over 2001-2019. The main drivers of inequality were unequal initial conditions/opportunities which, in turn, were reflected into differences in human capital, skills and economic status. Since the results have already been listed in the Introduction, we close with a possible extension. It would be interesting to study how the aggregate and distributional effects of the above studied public policies depend on institutional quality and in particular on government efficiency and the quality of the public sector. We leave this for future work.

Competing interests

The authors declare no conflict of/competing interests.

Data availability

The authors confirm that all data generated or analysed during this study are included in this article.

[21] It is important to note however that the effects of R2 depend on the value of κ in the motion for human capital. As κ rises, R2 becomes more and more like R1 so it becomes a win-win policy.

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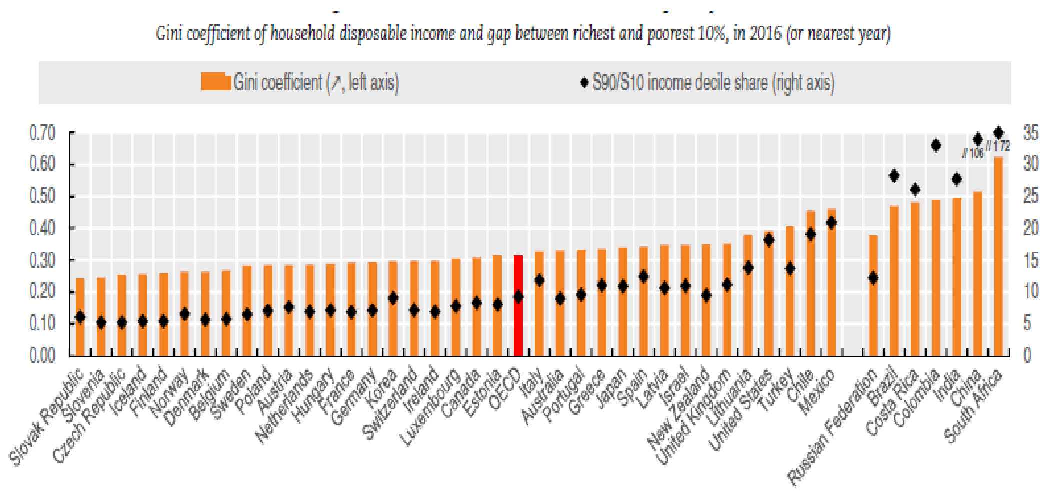
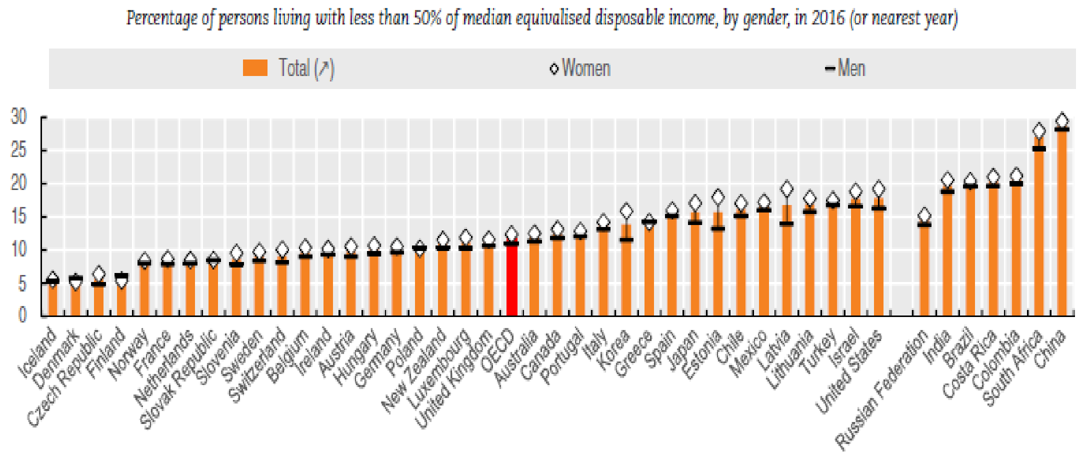
Tables

Table 1a: Income inequality across OECD countries



Source: OECD Income Distribution Database, http://oe.cd/idd.

Table 1b: Poverty rates across OECD countries



Source: OECD Income Distribution Database, http://oe.cd/idd.

Table 1c: Risk of poverty of current adults and the financial situation of their parents

At-risk-of poverty rate for current adults by financial situation of their households when respondent was around 14 years old
(% of specified population)

	2011		2019	
	Bad	Good	Bad	Good
EU	21.1	13.7	23.0	13.4
Belgium	22.2	9.7	20.6	10.2
Bulgaria	34.1	12.8	40.1	12.5
Czechia	11.5	8.9	10.2	5.9
Denmark	9.3	9.2	10.3	11.1
Germany	15.9	14.0	16.9	12.0
Estonia	23.1	15.6	15.1	13.3
Ireland	16.5	11.9	14.8	8.7
Greece	25.2	15.9	28.3	14.8
Spain	25.9	15.4	30.0	16.6
France	13.3	11.1	13.8	11.6
Croatia	21.7	14.9	19.4	10.9
Italy	26.5	15.2	30.7	15.9
Cyprus	16.4	7.3	17.4	9.6
Latvia	25.1	18.3	16.6	16.0
Lithuania	26.5	16.4	24.6	12.8
Luxembourg	20.7	9.8	22.1	14.6
Hungary	18.2	10.3	16.2	10.3
Malta	14.9	11.3	16.0	11.2
Netherlands	14.4	7.9	16.2	9.6
Austria	12.6	12.0	12.4	11.7
Poland	21.1	14.8	19.2	12.3
Portugal	20.5	10.3	23.2	12.1
Romania	28.4	15.5	32.7	15.6
Slovenia	12.0	11.2	11.4	9.1
Slovakia	14.8	11.4	19.1	7.9
Sweden	12.2	11.0	15.9	13.0
Finland	10.1	10.1	10.5	8.5
Iceland	10.5	8.7	:	:
Norway	7.5	7.0	18.2	11.2
Switzerland	11.7	9.9	9.6	11.5
United Kingdom	14.7	11.7		:
North Macedonia	:	:	32.9	13.0
Montenegro	:	:	35.5	14.6
Turkey	23.6	14.3	:	:
Serbia	:	:	29.3	17.3
Albania	:	:	25.3	19.2

: not available
Source: Eurostat, EU-SILC 2011 and 2019 ad-hoc module 'Intergenerational transmission of disadvantages'

eurostat

Table 1d: Risk of poverty of current adults and the education level of their parents

At-risk-of poverty rate for current adults by educational attainment level of their parents

(% of specified population)

	2011			2019		
	Low (ISCED level 0 - 2) or very low (could neither read nor write)	Medium (ISCED level 3 and 4)	High (ISCED level 5 and 6)	Low (ISCED level 0 - 2) or very low (could neither read nor write)	Medium (ISCED level 3 and 4)	High (ISCED level 5 - 8)
EU	19.8	11.2	9.4	20.3	12.0	8.6
Belgium	15.7	9.0	6.9	17.7	8.3	7.3
Bulgaria	28.4	8.3	2.8	33.7	9.2	3.6
Czechia	12.3	6.9	4.2	9.3	5.3	2.3
Denmark	8.6	6.3	14.1	9.4	9.6	11.9
Germany	22.1	12.7	12.1	15.6	11.7	10.6
Estonia	25.4	16.9	11.1	20.1	14.8	10.9
Ireland	16.2	12.1	10.9	15.0	7.9	6.1
Greece	21.8	11.6	7.1	22.2	11.6	9.3
Spain	20.1	15.8	11.6	22.4	17.1	11.4
France	13.0	8.4	8.5	14.4	9.1	6.7
Croatia	24.0	12.5	8.0	18.9	10.2	4.7
Italy	21.3	11.0	11.4	22.7	12.8	9.0
Cyprus	12.4	8.2	6.6	14.7	9.6	5.5
Latvia	28.6	16.9	12.1	28.5	14.9	9.3
Lithuania	23.9	16.6	10.1	23.8	14.8	7.5
Luxembourg	18.9	8.2	3.5	22.2	10.8	10.6
Hungary	17.9	7.8	4.2	14.7	10.7	9.0
Malta	14.6	7.6	4.5	16.1	10.9	7.5
Netherlands	10.0	6.9	9.4	10.3	8.4	9.0
Austria	15.2	10.5	10.9	14.3	8.7	14.8
Poland	22.6	13.2	7.9	22.7	11.6	6.5
Portugal	15.9	6.2	6.7	17.1	9.4	6.8
Romania	:	:	:	37.4	13.7	3.2
Slovenia	15.2	10.0	6.6	13.6	8.5	7.1
Slovakia	19.0	9.8	5.2	14.4	6.1	4.1
Sweden	8.7	9.7	11.3	18.0	10.2	12.7
Finland	11.5	9.2	9.2	10.3	7.0	9.6
Iceland	9.5	9.0	9.3	:	:	:
Norway	8.2	6.1	8.2	15.8	9.8	13.9
Switzerland	16.0	7.7	7.5	18.4	9.1	9.0
United Kingdom	15.0	9.3	9.2	:	:	:
North Macedonia	:	:	:	30.0	9.3	4.0
Montenegro	:	:	:	35.0	15.2	7.1
Turkey	19.9	3.2	1.7	:	:	:
Serbia	:	:	:	33.6	17.0	8.2
Albania	:	:	:	26.3	13.5	10.6

: not available
Source: Eurostat, EU-SILC 2011 and 2019 ad-hoc module 'Intergenerational transmission of disadvantages'

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Table 2a: Baseline parameter values

Parameter	Value	Description
β	0.985^{25}	Time discount rate
σ	1	Elasticity of inter-temporal substitution in utility
χ_n	12	Preference parameter related to effort
χ_b	5	Preference parameter related to bequests
χ_g	1	Preference parameter related to public consumption
η	1	Inverse of Frisch labour supply elasticity in utility
η_g	1	Exponent on public consumption in utility
η_b	1	Exponent on bequests in utility
A	1	TFP in production of goods
A^s, A^u	1	Labor productivity (skilled, unskilled)
$\frac{1}{1-\alpha}$	1.43	Elasticity of unskilled labor in production ($\alpha = 0.3$)
$\frac{1}{1-\psi}$	0.67	Elasticity of capital in production ($\psi = -0.49$)
ε	0.02	Elasticity of public capital in production
μ	0.28	Importance of physical capital in production
λ	0.3	Importance of unskilled labor in production
B^r, B^p	10, 8	TFP in production of human capital (skilled, unskilled)
θ	0.75	Productivity of education time
κ	0.5	Contribution of health to human capital
$\frac{1}{1-\nu}$	2	Elasticity of human capital ($\nu = 0.5$)
γ	0.25	Importance of private spending for human capital
δ^k, δ^g	1	Depreciation rates of physical and public capital
$\delta^{r,h}, \delta^{p,h}$	0.3	Depreciation rates of human capital
ν^r, ν^p	0.003,0.01	Birth rates
δ^r, δ^p	0.03	Death rates
n	0.008	Population growth rate

Table 2b: Policy variables used in the solution for 2019

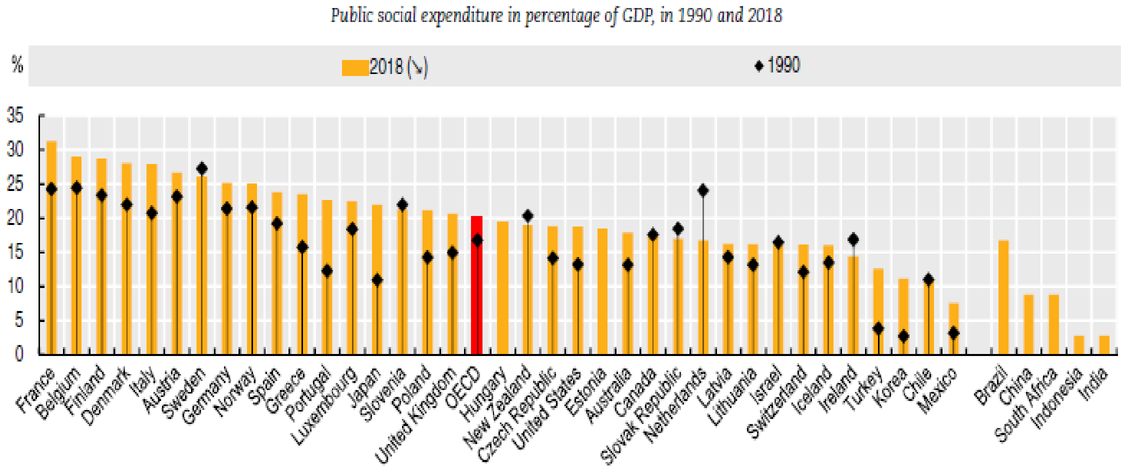
Policy instruments	Value	Description
τ^c	0.17	consumption tax rate
τ^k	0.21	personal capital income tax rate
τ^n	0.13	labor income tax rate (excluding social security contributions)
τ_t^s	0.13	social security contribution rate paid by employees
τ_t^w	0.13	social security contribution rate paid by employers
τ^f	0.21	corporate tax rate
τ^b	0.05	bequest tax rate
$s_t^{g^e}$	0.04	government spending on education as share of GDP
$s_t^{g^h}$	0.053	government spending on health as share of GDP
$s_t^{g^i}$	0.04	government spending on infrastructure as share of GDP
$s_t^{g^s}$	0.155	government spending on social protection (pensions) as share of GDP
$s_t^{g^t}$	0.06	government spending on transfers as share of GDP (excluding pensions)
$s_t^{g^c}$	0.12	government spending on the rest as share of GDP
$\zeta_t^{g^e}$	0.25	fraction of public spending on education allocated to the rich (set at n^r)
$\zeta_t^{g^h}$	0.25	fraction of public spending on health allocated to the rich (set at n^r)
$\zeta_t^{g^s}$	0.25	fraction of public spending on pensions allocated to the rich (set at n^r)
$\zeta_t^{g^t}$	0.25	fraction of public spending on transfers allocated to the poor (set at n^r)
λ^{EU}	0.7	share of total public debt held by EU public institutions
λ^{EU}	0.1	share of total public debt held by foreign private agents
r^*	1.22%	interest rate on foreign assets
r^{eu}	1%	interest rate on EU loans

Table 2c: Structure of public spending in 2019

Type of spending	% of GDP	% of total public spending
Social protection	19.80	41.70
Health	5.30	11.20
General public services	7.90	16.70
Education	4.00	8.30
Economic affairs	4.00	8.30
Public order and safety	2.10	4.00
Defence	2.00	4.00
Environmental protection	1.40	2.90
Housing and community amenities	0.20	0.40
Recreation and culture	0.80	1.70
Total	47.50	

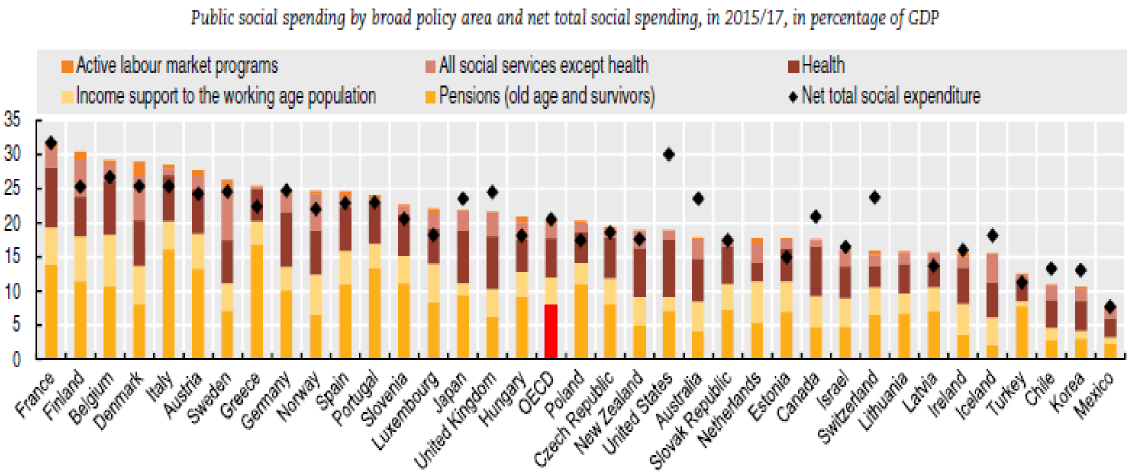
Source: Eurostat, Government finance statistics, Government expenditures by function - COFOG

Table 2d: Public social spending across OECD countries



Source: OECD (2019), *Social Expenditure database* (SOCX), *http://oe.cd/socx* and OECD (2019), *Society at a Glance: Asia/Pacific 2019*, OECD Publishing, Paris.

Table 2e: Categories of public social spending across OECD countries



Source: OECD (2019), *Social Expenditure database* (SOCX), *http://oe.cd/socx*.

Table 2f: Structure of tax revenues in 2019

Type of tax	% of GDP	% of total tax revenues
SSC (Employers)	5.60	14.10
SSC (Employees)	6.60	16.10
Consumption	14.90	27.80
Labour income (excluding SSC)	4.20	11.50
Capital income (non-corporate)	4.70	15.10
Capital income (corporate)	2.20	5.60

(i) Source: European Commission, Taxation Trends in the EU; author's calculations

(ii) "Total' indicates the total tax revenues of the listed types of tax in the tables.

(iii) We do not include other types of taxes like environmental taxes, property taxes, etc.

Table 3: Initial steady state solution (year 2019)

Variable	Solution	Data
$c/y = \frac{n^{r,y}(c^{r,y}+c^{r,m}+c^{r,o})+n^{p,y}(c^{p,y}+c^{p,m}+c^{p,o})}{n^{r,m}y}$	0.604	0.630
$i/y = \frac{n^{r,m}k^{r,m}}{n^{r,m}y}$	0.153	0.238
$z/y = \frac{n^{r,y}z^{r,y}+n^{p,y}z^{p,y}}{n^{r,m}y}$	0.0028	0.0012
$d/y = \frac{n^{r,m}d^{r,m}}{n^{r,m}y}$	1.807	1.84
r^d	2.2%	2.2%
w^r/w^p	1.60	1.52
n^r	0.230	0.278
n^p	0.770	0.722
$y^{net,r}$	0.017	-
$y^{net,p}$	0.042	-
$y^{net,r}/y^{net,p}$	4.094	-

Table 4: Reforms studied

R1: Increase in s^{g^e}
R2: Increase in s^{g^h}
R3: Increase in s^{g^s}
R4: Decrease in ζ^{g^e}
R5: Decrease in ζ^{g^h}
R6: Decrease in ζ^{g^s}
R7: Increase in τ^b
R8: FF public pension system

Table 5: Steady state solutions

	Status-quo	R1	R2	R3	R4	R5	R6	R7	R8
y^f	0.2698	0.2787	0.2732	0.2666	0.2555	0.2620	0.2920	0.2790	0.2770
k^f	0.0410	0.0423	0.0415	0.0405	0.0376	0.0391	0.0455	0.0428	0.0422
$y^{r,net}$	0.1737	0.1753	0.1718	0.1693	0.1639	0.1684	0.1675	0.1762	0.1974
$y^{p,net}$	0.0424	0.0430	0.0421	0.0418	0.0410	0.0417	0.0479	0.0443	0.0471
$y^{r,net}/y^{p,net}$	4.0940	4.0779	4.0786	4.0550	4.0015	4.0392	3.4928	3.9729	4.1875
$h^{r,m}$	1.0950	1.1277	1.1079	1.0835	0.9311	0.9964	1.1799	1.1298	1.1194
$h^{p,m}$	0.8124	0.8468	0.8285	0.8088	0.8402	0.8328	0.8272	0.8199	0.8232
$c^{r,y}$	0.0230	0.0232	0.0228	0.0225	0.0215	0.0222	0.0212	0.0229	0.0258
$c^{r,m}$	0.0232	0.0234	0.0230	0.0227	0.0217	0.0224	0.0214	0.0231	0.0260
$c^{r,o}$	0.0214	0.0217	0.0212	0.0210	0.0201	0.0207	0.0198	0.0214	0.0240
$c^{p,y}$	0.0102	0.0103	0.0101	0.0099	0.0099	0.0101	0.0108	0.0107	0.0115
$c^{p,m}$	0.0103	0.0104	0.0102	0.0100	0.0100	0.0102	0.0109	0.0108	0.0116
$c^{p,o}$	0.0081	0.0084	0.0082	0.0085	0.0077	0.0079	0.0117	0.0084	0.0082
$s^{r,o}$	0.0105	0.0109	0.0107	0.0111	0.0100	0.0102	0.0000	0.0109	0.0108
$s^{p,o}$	0.0095	0.0098	0.0096	0.0100	0.0090	0.0092	0.0137	0.0098	0.0097
d/y	1.8077	1.8077	1.8077	1.8077	1.8077	1.8077	1.8077	1.8077	1.8077

Appendices

Appendix A: Households

A.1 Rich-born households

First-order conditions of rich-born households When young at t, the optimality for $e_t^{r,y}$ and $z_t^{r,y}$ are:

$$\chi_n \left(e_t^{r,y}\right)^{\eta} = \frac{\beta \left(c_{t+1}^{r,m}\right)^{-\sigma} \left(1 - \tau_{t+1}^{n} - \tau_{t+1}^{s}\right) w_{t+1}^{r} l_{t+1}^{r,m} \frac{\partial h_{t+1}^{r,m}}{\partial e_t^{r,y}}}{\left(1 + \tau_{t+1}^{c}\right)} \tag{A1}$$

$$\frac{\left(c_t^{r,y}\right)^{-\sigma}}{\left(1 + \tau_t^{c}\right)} = \frac{\beta \left(c_{t+1}^{r,m}\right)^{-\sigma} \left(1 - \tau_{t+1}^{n} - \tau_{t+1}^{s}\right) w_{t+1}^{r} l_{t+1}^{r,m} \frac{\partial h_{t+1}^{r,m}}{\partial z_t^{r,y}}}{\left(1 + \tau_{t+1}^{c}\right)} \tag{A2}$$

where we use:

$$\frac{\partial h_{t+1}^{r,m}}{\partial e_t^{r,y}} = B^r \theta \left(e_t^{r,y}\right)^{\theta - 1} \left[\gamma \left(z_t^{r,y}\right)^{\nu} + (1 - \gamma) \left(g_t^{r,e} + \kappa g_t^{r,h}\right)^{\nu}\right]^{\frac{1-\theta}{\nu}}$$

$$\frac{\partial h_{t+1}^{r,m}}{\partial z_t^{r,y}} = \frac{B^r \left(e_t^{r,y}\right)^{\theta} \gamma \left(1 - \theta\right) \left[\gamma \left(z_t^{r,y}\right)^{\nu} + (1 - \gamma) \left(g_t^{r,e} + \kappa g_t^{r,h}\right)^{\nu}\right]^{\frac{1-\theta}{\nu} - 1}}{\left(z_t^{r,y}\right)^{1-\nu}}$$

and where:

$$\Psi_{t+1}^{r,m} = \frac{n_{t+1}^{r,y}}{n_{t+1}^{r,m}} \Psi_{t+1}^{r,y}$$

In the beginning of adult life at $t+1$, the optimality conditions for $l_{t+1}^{r,m}$, $k_{t+1}^{r,m}$, $d_{t+1}^{r,m}$, $f_{t+1}^{r,m}$ and $\Psi_{t+1}^{r,y}$ are:

$$\chi_n \left(l_{t+1}^{r,m}\right)^{\eta} = \frac{\left(c_{t+1}^{r,m}\right)^{-\sigma} \left(1 - \tau_{t+1}^{n} - \tau_{t+1}^{s}\right) w_{t+1}^{r} h_{t+1}^{r,m}}{\left(1 + \tau_{t+1}^{c}\right)} \tag{A3}$$

$$\frac{\left(c_{t+1}^{r,m}\right)^{-\sigma}}{\left(1 + \tau_{t+1}^{c}\right)} = \frac{\beta \left(c_{t+2}^{r,o}\right)^{-\sigma} \left[1 - \delta^{k} + \left(1 - \tau_{t+2}^{k}\right) r_{t+2}^{k}\right]}{\left(1 + \tau_{t+2}^{c}\right)} \tag{A4}$$

$$\frac{\left(c_{t+1}^{r,m}\right)^{-\sigma}}{\left(1 + \tau_{t+1}^{c}\right)} = \frac{\beta \left(c_{t+2}^{r,o}\right)^{-\sigma} \left(1 + r_{t+2}^{d}\right)}{\left(1 + \tau_{t+2}^{c}\right)} \tag{A5}$$

$$\frac{\left(c_t^{r,m}\right)^{-\sigma}}{\left(1 + \tau_t^{c}\right)} [1 + x^{f} (\ f_t^{r,m} - \ f^{r,m})] = \frac{\beta \left(c_{t+1}^{r,o}\right)^{-\sigma} \left(1 + r_{t+1}^{*}\right)}{\left(1 + \tau_{t+1}^{c}\right)} \tag{A6}$$

$$\frac{n_{t+1}^{r,y}}{n_{t+1}^{r,m}} (c_{t+1}^{r,m})^{-\sigma} = (c_{t+1}^{r,y})^{-\sigma} \tag{A7}$$

And, finally, when the household reaches the old age, the optimality condition of the rich old for bequests is:

$$\frac{\left(c_{t+2}^{r,o}\right)^{-\sigma}}{\left(1+\tau_{t+2}^{c}\right)} = \beta\chi_b\left(b_{t+2}^{r,o}\right)^{-\eta_b} \tag{A8}$$

Motion of human capital In addition to the motion from young to adult which was defined in the main text, the motion from adult to old and the motion from old to young (so that we capture the persistence of human capital from one generation to another) are:

$$n_t^{r,o}h_t^{r,o} = \left(1-\delta^{r,h}\right)\frac{N_{t-1}}{N_t}n_{t-1}^{r,m}h_{t-1}^{r,m} \tag{A9}$$

$$n_t^{r,y}h_t^{r,y} = \left(1-\delta^{r,h}\right)\frac{N_{t-1}}{N_t}n_{t-1}^{r,o}h_{t-1}^{r,o} \tag{A10}$$

A.2 Poor-born households

First-order conditions of poor-born households When young at t, the optimality condition for $e_t^{p,y}$ is:

$$\chi_n\left(e_t^{p,y}\right)^{\eta} = \frac{\beta\left(c_{t+1}^{p,m}\right)^{-\sigma}\left(1-\tau_{t+1}^{n}-\tau_{t+1}^{s}\right)w_{t+1}^{p}l_{t+1}^{p,m}\frac{\partial h_{t+1}^{p,m}}{\partial e_t^{p,y}}}{\left(1+\tau_{t+1}^{c}\right)} \tag{A11}$$

where we use:

$$\frac{\partial h_{t+1}^{p,m}}{\partial e_t^{p,y}} = B^p\theta\left(e_t^{p,y}\right)^{\theta-1}\left[(1-\gamma)\left(g_t^{p,e}+\kappa g_t^{p,h}\right)^{\nu}\right]^{\frac{1-\theta}{\nu}}$$

and where:

$$\Psi_{t+1}^{r,m} = \frac{n_{t+1}^{r,y}}{n_{t+1}^{r,m}}\Psi_{t+1}^{r,y}$$

In adult life at $t+1$, the optimality conditions for $l_{t+1}^{p,m}$ and $\Psi_{t+1}^{p,y}$ are:

$$\chi_n\left(l_{t+1}^{p,m}\right)^{\eta} = \frac{\left(c_{t+1}^{p,m}\right)^{-\sigma}\left(1-\tau_{t+1}^{n}-\tau_{t+1}^{s}\right)w_{t+1}^{p}h_{t+1}^{p,m}}{\left(1+\tau_{t+1}^{c}\right)} \tag{A12}$$

$$\frac{n_{t+1}^{p,y}}{n_{t+1}^{p,m}}\left(c_{t+1}^{p,m}\right)^{-\sigma} = \left(c_{t+1}^{p,y}\right)^{-\sigma} \tag{A13}$$

Motion of human capital In addition to the motion from young to adult which was defined in the main text, the motion from adult to old and the motion from old to young (so that we capture the persistence of human capital from one generation to another) are:

$$n_t^{p,o} h_t^{p,o} = \left(1 - \delta^{p,h}\right) \frac{N_{t-1}}{N_t} n_{t-1}^{p,m} h_{t-1}^{p,m} \tag{A14}$$

$$n_t^{p,y} h_t^{p,y} = \left(1 - \delta^{p,h}\right) \frac{N_{t-1}}{N_t} n_{t-1}^{p,o} h_{t-1}^{p,o} \tag{A15}$$

Appendix A.3 Population shares

Let us define by ν_r and ν_p the exogenous birth rates of the two groups and by δ_r and δ_p their exogenous death rates. Then, we have the population levels for the 6 distinct social/age groups:

$$N_t^{r,y} \equiv (1 - \delta_r) X_{t-1}^r + \nu_r N_{t-1} \tag{A16}$$

$$N_t^{r,m} \equiv N_{t-1}^{r,y} \tag{A17}$$

$$N_t^{r,o} \equiv N_{t-1}^{r,m} \tag{A18}$$

$$N_t^{p,y} \equiv (1 - \delta_p) X_{t-1}^p + \nu_p N_{t-1} \tag{A19}$$

$$N_t^{p,m} \equiv N_{t-1}^{p,y} \tag{A20}$$

$$N_t^{p,o} \equiv N_{t-1}^{p,m} \tag{A21}$$

Since the total population at t, N_t, is:

$$N_t \equiv N_t^{p,y} + N_t^{r,y} + N_t^{p,m} + N_t^{r,m} + N_t^{p,o} + N_t^{r,o} \tag{A22}$$

we have for the motion of N_t over time:

$$N_t = (1 + \nu_r + \nu_p) N_{t-1} - N_{t-1}^{r,o} - N_{t-1}^{p,o} + (1 - \delta_r) N_{t-1}^{r,y} + (1 - \delta_p) N_{t-1}^{p,y} \tag{A23}$$

In terms of population shares, the above are rewritten as:

$$n_t^{r,y} \equiv \frac{N_t^{r,y}}{N_t} = \frac{N_{t-1}}{N_t}[(1-\delta_r)x_{t-1}^r + \nu_r] \tag{A24}$$

$$n_t^{r,m} \equiv \frac{N_t^{r,m}}{N_t} = \frac{N_{t-1}}{N_t}n_{t-1}^{r,y} \tag{A25}$$

$$n_t^{r,o} \equiv \frac{N_t^{r,o}}{N_t} = \frac{N_{t-1}}{N_t}n_{t-1}^{r,m} \tag{A26}$$

$$n_t^{p,y} \equiv \frac{N_t^{p,y}}{N_t} = \frac{N_{t-1}}{N_t}[(1-\delta_p)x_{t-1}^p + \nu_p] \tag{A27}$$

$$n_t^{p,m} \equiv \frac{N_t^{p,m}}{N_t} = \frac{N_{t-1}}{N_t}n_{t-1}^{p,y} \tag{A28}$$

$$n_t^{p,o} \equiv \frac{N_t^{p,o}}{N_t} = \frac{N_{t-1}}{N_t}n_{t-1}^{p,m} \tag{A29}$$

$$\frac{N_t}{N_{t-1}} = 1 + \nu_r + \nu_p - n_{t-1}^{r,o} - n_{t-1}^{p,o} + (1-\delta_r)x_{t-1}^r + (1-\delta_p)x_{t-1}^p \tag{A30}$$

where we set $x_{t-1}^r \equiv n_{t-1}^{r,y}$ and $x_{t-1}^p \equiv n_{t-1}^{p,y}$. In our solutions, we set $\delta_r = 0.03$, $\delta_p = 0.03$, $\nu_r = 0.002$, $\nu_p = 0.01$.

Appendix B: Firms

The first-order conditions for k_t^f, $l_t^{r,f}$ and $l_t^{p,f}$ are respectively:

$$r_t^k = (1-\tau_t^f)\frac{\partial y_t^f}{\partial k_t^f} \tag{B1}$$

$$(1+\tau_t^w-\tau_t^f)w_t^r = (1-\tau_t^f)\frac{\partial y_t^f}{\partial l_t^{r,f}} \tag{B2}$$

$$(1+\tau_t^w-\tau_t^f)w_t^p = (1-\tau_t^f)\frac{\partial y_t^f}{\partial l_t^{p,f}} \tag{B3}$$

where we use:

$$\frac{\partial y_t^f}{\partial k_t^f} = \frac{(1-\varepsilon)y_t^f(1-\lambda)[\mu(k_t^f)^\psi + (1-\mu)(l_t^{r,f})^\psi]^{\frac{\alpha}{\psi}-1}\mu(k_t^f)^{\psi-1}}{\left(\lambda(l_t^{p,f})^\alpha + (1-\lambda)[\mu(k_t^f)^\psi + (1-\mu)(l_t^{r,f})^\psi]^{\frac{\alpha}{\psi}}\right)}$$

$$\frac{\partial y_t^f}{\partial l_t^{r,f}} = \frac{(1-\varepsilon)y_t^f(1-\lambda)[\mu(k_t^f)^\psi + (1-\mu)(l_t^{r,f})^\psi]^{\frac{\alpha}{\psi}-1}(1-\mu)(l_t^{r,f})^{\psi-1}}{\left(\lambda(l_t^{p,f})^\alpha + (1-\lambda)[\mu(k_t^f)^\psi + (1-\mu)(l_t^{r,f})^\psi]^{\frac{\alpha}{\psi}}\right)}$$

$$\frac{\partial y_t^f}{\partial l_t^{p,f}} = \frac{(1-\varepsilon) y_t^f \lambda (l_t^{p,f})^{\alpha-1}}{\left(\lambda (l_t^{p,f})^{\alpha} + (1-\lambda)[\mu (k_t^f)^{\psi} + (1-\mu)(l_t^{r,f})^{\psi}]^{\frac{\alpha}{\psi}}\right)}$$

Appendix C: Macroeconomic system

Collecting all equations and writing them as at time t, the final system we solve numerically is:

Rich-born and skilled households

$$(1+\tau_t^c)\, c_t^{r,y} + z_t^{r,y} = \left(1-\tau_t^b\right) b_{t-1}^{r,y} + \Psi_t^{r,y} \tag{C1}$$

$$(1+\tau_t^c)\, c_t^{r,m} + k_t^{r,m} + d_t^{r,m} + \ + f_t^{r,m} + \frac{x^f}{2}(\ f_t^{r,m} - \ f^{r,m})^2 \frac{n_t^{r,y}}{n_t^{r,m}} + \Psi_t^{r,y} =$$

$$= (1-\tau_t^n - \tau_t^s)\, w_t^r h_t^{r,m} l_t^{r,m} + g_t^{t,r,m} \tag{C2}$$

$$(1+\tau_t^c)\, c_t^{r,o} + b_t^{r,o} = \left[1-\delta^k + \left(1-\tau_t^k\right) r_t^k\right] k_{t-1}^{r,m} + \left(1-\tau_t^k\right) \pi_t^{r,o} + \left(1+r_t^d\right) d_{t-1}^{r,m} + (1+r_t^*)\, f_{t-1}^{r,m} + s_t^{r,o} \tag{C3}$$

$$n_t^{r,m} h_t^{r,m} = \frac{N_{t-1}}{N_t} n_{t-1}^{r,y} \left[\left(1-\delta^{r,h}\right) h_{t-1}^{r,y} + B\left(e_{t-1}^{r,y}\right)^{\theta} \left[\gamma \left(z_{t-1}^{r,y}\right)^{\nu} + (1-\gamma)\left(g_{t-1}^{r,e} + \kappa g_{t-1}^{r,h}\right)^{\nu}\right]^{\frac{1-\theta}{\nu}}\right] \tag{C4}$$

$$\chi_n \left(e_t^{r,y}\right)^{\eta} = \frac{\beta \left(c_{t+1}^{r,m}\right)^{-\sigma} \left(1-\tau_{t+1}^n - \tau_{t+1}^s\right) w_{t+1}^r l_{t+1}^{r,m} \frac{\partial h_{t+1}^{r,m}}{\partial e_t^{r,y}}}{\left(1+\tau_{t+1}^c\right)} \tag{C5}$$

$$\frac{\left(c_t^{r,y}\right)^{-\sigma}}{\left(1+\tau_t^c\right)} = \frac{\beta \left(c_{t+1}^{r,m}\right)^{-\sigma} \left(1-\tau_{t+1}^n - \tau_{t+1}^s\right) w_{t+1}^r l_{t+1}^{r,m} \frac{\partial h_{t+1}^{r,m}}{\partial z_t^{r,y}}}{\left(1+\tau_{t+1}^c\right)} \tag{C6}$$

$$\chi_n \left(l_t^{r,m}\right)^{\eta} = \frac{\left(c_t^{r,m}\right)^{-\sigma} (1-\tau_t^n - \tau_t^s)\, w_t^r h_t^{r,m}}{(1+\tau_t^c)} \tag{C7}$$

$$\frac{\left(c_t^{r,m}\right)^{-\sigma}}{\left(1+\tau_t^c\right)} = \frac{\beta \left(c_{t+1}^{r,o}\right)^{-\sigma} \left[1-\delta^k + \left(1-\tau_{t+1}^k\right) r_{t+1}^k\right]}{\left(1+\tau_{t+1}^c\right)} \tag{C8}$$

$$\frac{\left(c_t^{r,m}\right)^{-\sigma}}{\left(1+\tau_t^c\right)} = \frac{\beta \left(c_{t+1}^{r,o}\right)^{-\sigma} \left(1+r_{t+1}^d\right)}{\left(1+\tau_{t+1}^c\right)} \tag{C9}$$

$$\frac{\left(c_t^{r,m}\right)^{-\sigma}}{\left(1+\tau_t^c\right)} [1 + x^f(\ f_t^{r,m} - \ f^{r,m})] = \frac{\beta \left(c_{t+1}^{r,o}\right)^{-\sigma} \left(1+r_{t+1}^*\right)}{\left(1+\tau_{t+1}^c\right)} \tag{C10}$$

$$\frac{\left(c_t^{r,o}\right)^{-\sigma}}{\left(1+\tau_t^c\right)} = \beta\chi_b \left(b_t^{r,o}\right)^{-\eta_b} \tag{C11}$$

$$\frac{n_t^{r,y}}{n_t^{r,m}}\left(c_t^{r,m}\right)^{-\sigma} = \left(c_t^{r,y}\right)^{-\sigma} \tag{C12}$$

where we use:

$$\frac{\partial h_{t+1}^{r,m}}{\partial e_t^{r,y}} = B^r\theta \left(e_t^{r,y}\right)^{\theta-1}\left[\gamma\left(z_t^{r,y}\right)^{\nu} + (1-\gamma)\left(g_t^{r,e}+\kappa g_t^{r,h}\right)^{\nu}\right]^{\frac{1-\theta}{\nu}}$$

$$\frac{\partial h_{t+1}^{r,m}}{\partial z_t^{r,y}} = \frac{B^r\left(e_t^{r,y}\right)^{\theta}\gamma\left(1-\theta\right)\left[\gamma\left(z_t^{r,y}\right)^{\nu} + (1-\gamma)\left(g_t^{r,e}+\kappa g_t^{r,h}\right)^{\nu}\right]^{\frac{1-\theta}{\nu}-1}}{\left(z_t^{r,y}\right)^{1-\nu}}$$

In this block, we have 12 equations for the paths of $c_t^{r,y}$, $c_{t,}^{r,m}$, $c_t^{r,o}$, $e_t^{r,y}$, $z_t^{r,y}$, $l_t^{r,m}$, $k_t^{r,m}$, $d_t^{r,m}$, $f_t^{r,m}$, $b_t^{r,o}$, $h_t^{r,m}$, $\Psi_t^{r,y}$.

Poor-born and unskilled households

$$\left(1+\tau_t^c\right)c_t^{p,y} = \Psi_t^{p,y} \tag{C13}$$

$$(1+\tau_t^c)c_t^{p,m} + \frac{n_t^{p,y}}{n_t^{p,m}} + \Psi_t^{p,y}] = \left(1-\tau_t^n-\tau_t^s\right)w_t^p h_t^{p,m} l_t^{p,m} + g_t^{t,p,m}] \tag{C14}$$

$$\left(1+\tau_t^c\right)c_t^{p,o} = s_t^{p,o} \tag{C15}$$

$$n_t^{p,m}h_t^{p,m} = \frac{N_{t-1}}{N_t}n_{t-1}^{p,y}\left[\left(1-\delta^{p,h}\right)h_{t-1}^{p,y} + B^p\left(e_{t-1}^{p,y}\right)^{\theta}\left[(1-\gamma)\left(g_{t-1}^{p,e}+\kappa g_{t-1}^{p,h}\right)^{\nu}\right]^{\frac{1-\theta}{\nu}}\right] \tag{C16}$$

$$\chi_n\left(e_t^{p,y}\right)^{\eta} = \frac{\beta\left(c_{t+1}^{p,m}\right)^{-\sigma}\left(1-\tau_{t+1}^n-\tau_{t+1}^s\right)w_{t+1}^p l_{t+1}^{p,m}\frac{\partial h_{t+1}^{p,m}}{\partial e_t^{p,y}}}{\left(1+\tau_{t+1}^c\right)} \tag{C17}$$

$$\chi_n\left(l_t^{p,m}\right)^{\eta} = \frac{\left(c_t^{p,m}\right)^{-\sigma}\left(1-\tau_t^n-\tau_t^s\right)w_t^p h_t^{p,m}}{\left(1+\tau_t^c\right)} \tag{C18}$$

$$\frac{n_t^{p,y}}{n_t^{p,m}}\left(c_t^{p,m}\right)^{-\sigma} = \left(c_t^{p,y}\right)^{-\sigma} \tag{C19}$$

where we use:

$$\frac{\partial h_{t+1}^{p,m}}{\partial e_t^{p,y}} = B^p\theta\left(e_t^{p,y}\right)^{\theta-1}\left[(1-\gamma)\left(g_t^{p,e}+\kappa g_t^{p,h}\right)^{\nu}\right]^{\frac{1-\theta}{\nu}}$$

In this block, we have 7 equations for the paths of $c_t^{p,y}$, $c_{t,}^{p,m}$, $c_t^{p,o}$, $e_t^{p,y}$, $l_t^{p,m}$, $h_{t+1}^{p,m}$, $\Psi_t^{p,y}$.

Market-clearing condition in the market for bequests

$$n_t^{r,y} b_{t-1}^{r,y} = \frac{N_{t-1}}{N_t} n_{t-1}^{r,o} b_{t-1}^{r,o} \tag{C20}$$

In this block, we have 1 equation for the path of $b_t^{r,y}$.

Equations for the motion of human capital in all other ages In addition to the two motions from young to adult which were defined above, we model, for each group, the motion from adult to old and the motion for old to young (so we capture the persistence of human capital from one generation to another). Thus,

$$n_t^{r,o} h_t^{r,o} = \left(1 - \delta^{r,h}\right) \frac{N_{t-1}}{N_t} n_{t-1}^{r,m} h_{t-1}^{r,m} \tag{C21}$$

$$n_t^{r,y} h_t^{r,y} = \left(1 - \delta^{r,h}\right) \frac{N_{t-1}}{N_t} n_{t-1}^{r,o} h_{t-1}^{r,o} \tag{C22}$$

$$n_t^{p,o} h_t^{p,o} = \left(1 - \delta^{p,h}\right) \frac{N_{t-1}}{N_t} n_{t-1}^{p,m} h_{t-1}^{p,m} \tag{C23}$$

$$n_t^{p,y} h_t^{p,y} = \left(1 - \delta^{p,h}\right) \frac{N_{t-1}}{N_t} n_{t-1}^{p,o} h_{t-1}^{p,o} \tag{C24}$$

In this block, we have 4 equations for the paths of $h_t^{r,o}$, $h_t^{r,y}$, $h_t^{p,o}$ and $h_t^{p,y}$.

Firms

$$n_t^f y_t^f = A \left(\lambda (n_t^f l_t^{p,f})^\alpha + (1-\lambda)[\mu (n_t^f k_t^f)^\psi + (1-\mu)(n_t^f l_t^{r,f})^\psi]^{\frac{\alpha}{\psi}}\right)^{\frac{1-\varepsilon}{\alpha}} (k_t^g)^\varepsilon \tag{C25}$$

$$r_t^k = (1 - \tau_t^f) \frac{\partial y_t^f}{\partial k_t^f} \tag{C26}$$

$$(1 + \tau_t^w - \tau_t^f) w_t^r = (1 - \tau_t^f) \frac{\partial y_t^f}{\partial l_t^{r,f}} \tag{C27}$$

$$(1 + \tau_t^w - \tau_t^f) w_t^p = (1 - \tau_t^f) \frac{\partial y_t^f}{\partial l_t^{p,f}} \tag{C28}$$

$$\pi_t^f \equiv y_t^f - (1 + \tau_t^w)(w_t^r l_t^{r,f} + w_t^p l_t^{p,f}) - r_t^k k_t^f - \tau_t^f (y_t^f - w_t^r l_t^{r,f} - w_t^p l_t^{p,f}) \tag{C29}$$

where we use:

$$\frac{\partial y_t^f}{\partial k_t^f} = \frac{(1-\varepsilon) y_t^f (1-\lambda)[\mu (k_t^f)^\psi + (1-\mu)(l_t^{r,f})^\psi]^{\frac{\alpha}{\psi}-1} \mu (k_t^f)^{\psi-1}}{\left(\lambda (l_t^{p,f})^\alpha + (1-\lambda)[\mu (k_t^f)^\psi + (1-\mu)(l_t^{r,f})^\psi]^{\frac{\alpha}{\psi}}\right)}$$

$$\frac{\partial y_t^f}{\partial l_t^{r,f}} = \frac{(1-\varepsilon)y_t^f(1-\lambda)[\mu(k_t^f)^\psi + (1-\mu)(l_t^{r,f})^\psi]^{\frac{\alpha}{\psi}-1}(1-\mu)(l_t^{r,f})^{\psi-1}}{\left(\lambda(l_t^{p,f})^\alpha + (1-\lambda)[\mu(k_t^f)^\psi + (1-\mu)(l_t^{r,f})^\psi]^{\frac{\alpha}{\psi}}\right)}$$

$$\frac{\partial y_t^f}{\partial l_t^{p,f}} = \frac{(1-\varepsilon)y_t^f\lambda(l_t^{p,f})^{\alpha-1}}{\left(\lambda(l_t^{p,f})^\alpha + (1-\lambda)[\mu(k_t^f)^\psi + (1-\mu)(l_t^{r,f})^\psi]^{\frac{\alpha}{\psi}}\right)}$$

In this block, we have 5 equations for the paths of y_t^f, r_t^k, w_t^r, w_t^p, π_t^f.

Market-clearing conditions in the factor markers

$$l_t^{p,f} = \frac{n_t^{p,m} l_t^{p,m} h_t^{p,m}}{n_t^f} \tag{C30}$$

$$l_t^{r,f} = \frac{n_t^{r,m} l_t^{r,m} h_t^{r,m}}{n_t^f} \tag{C31}$$

$$k_t^f = \frac{\frac{N_{t-1}}{N_t} n_{t-1}^{r,m} k_{t-1}^{r,m}}{n_t^f} \tag{C32}$$

$$\pi_t^f = \frac{\frac{N_{t-1}}{N_t} n_{t-1}^{r,m} \pi_t^{r,o}}{n_t^f} \tag{C33}$$

In this block, we have 4 equations for the pathhs of $l_t^{p,f}$, $l_t^{r,f}$, k_t^f, $\pi_t^{r,o}$.

Government budget constraint Under a fully funded PAYG system, we would have two separate government budget constraints:

$$[s_t^{g^h} + s_t^{g^e} + s_t^{g^t} + s_t^{g^w} + s_t^{g^i} + s_t^{g^c}] n_t^f y_t^f + \left(1+r_t^d\right)(\lambda_{t-1}^d + \lambda_{t-1}^f)\frac{N_{t-1}}{N_t} d_{t-1} + (1+r_t^{eu})\,\lambda_{t-1}^{eu}\frac{N_{t-1}}{N_t} d_{t-1} = d_t + \frac{T_t}{N_t}$$

$$s_t^{g^s} n_t^f y_t^f = \tau_t^s[n_t^{r,m} w_t^r l_t^{r,m} h_t^{r,m} + n_t^{p,m} w_t^p l_t^{p,m} h_t^{p,m}] + \tau_t^w n_t^f (w_t^r l_t^{r,f} + w_t^p l_t^{p,f})$$

which determine the end-of-period total public debt expressed in per capita terms, d_t, and one of the two social security tax rates, τ_t^s or τ_t^s. Note that $0 \leq \lambda_t^d, \lambda_t^f, \lambda_t^{eu} < 1$, where $\lambda_t^d + \lambda_t^f + \lambda_t^{eu} = 1$ in each t, denote respectively the fractions of total public debt held by domestic private agents, foreign private agents and non-market EU institutions (like ESM, ES, etc).

Under a partially funded PAYG system, which is closer to the Greek reality, we have a single budget constraint:

$$[s_t^{g^h} + s_t^{g^e} + s_t^{g^t} + s_t^{g^w} + s_t^{g^i} + s_t^{g^c}]n_t^f y_t^f + \left(1 + r_t^d\right)(\lambda_{t-1}^d + \lambda_{t-1}^f)\frac{N_{t-1}}{N_t}d_{t-1} + (1 + r_t^{eu})\,\lambda_{t-1}^{eu}\frac{N_{t-1}}{N_t}d_{t-1} +$$

$$+ s_t^{g^s} n_t^f y_t^f - \tau_t^s[n_t^{r,m} w_t^r l_t^{r,m} h_t^{r,m} + n_t^{p,m} w_t^p l_t^{p,m} h_t^{p,m}] - \tau_t^w n_t^f (w_t^r l_t^{r,f} + w_t^p l_t^{p,f}) = d_t + \frac{T_t}{N_t} \tag{C34}$$

where we use:

$$\lambda_t^d = 1 - \lambda_t^f - \lambda_t^{eu}$$

$$\lambda_t^d d_t = n_t^{r,m} d_t^{r,m}$$

The per capita tax revenues (all sources except SSCs which have already been included in the single government budget constraint) are:

$$\frac{T_t}{N_t} \equiv \tau_t^c (n_t^{r,y} c_t^{r,y} + n_t^{r,m} c_t^{r,m} + n_t^{r,o} c_t^{r,o} + n_t^{p,y} c_t^{p,y} + n_t^{p,m} c_t^{p,m} + n_t^{p,o} c_t^{p,o}) +$$

$$+ \tau_t^n (n_t^{r,m} w_t^r l_t^{r,m} h_t^{r,m} + n_t^{p,m} w_t^p l_t^{p,m} h_t^{p,m}) + \tau_t^k \frac{N_{t-1}}{N_t} n_{t-1}^{r,m} (r_t k_{t-1}^{r,m} + \pi_t^{r,o}) +$$

$$+ \tau_t^b n_t^{r,y} b_{t-1}^{r,y} + \tau_t^f n_t^f \left(y_t^f - w_t^r l_t^{r,f} - w_t^p l_t^{p,f}\right) \tag{C35}$$

The law of motion for public capital (per capita):

$$\frac{N_{t+1}}{N_t} k_{t+1}^g = (1 - \delta^g)\, k_t^g + s_t^{g^i} n_t^f y_t^f \tag{C36}$$

In this block, under a partially funded PAYG system in which we use the merged budget constraint, we have 3 equations for the paths of $d_t^{r,m}$, $\frac{T_t}{N_t}$, k_{t+1t}^g.

Government spending items and their allocation to the two groups

$$g_t^{r,h} \equiv \frac{G_t^{r,h}}{N_t^{r,y}} = \frac{\zeta_t^h G_t^h}{N_t^{r,y}} = \frac{\zeta_t^h s_t^{g^h} N_t^f y_t^f}{N_t^{r,y}} = \frac{\zeta_t^h s_t^{g^h} n_t^f y_t^f}{n_t^{r,y}} \tag{C37}$$

$$g_t^{p,h} \equiv \frac{G_t^{p,h}}{N_t^{p,y}} = \frac{(1-\zeta_t^h)s_t^{g^h} N_t^f y_t^f}{N_t^{p,y}} = \frac{(1-\zeta_t^h)s_t^{g^h} n_t^f y_t^f}{n_t^{p,y}} \tag{C38}$$

$$g_t^{r,e} \equiv \frac{G_t^{r,e}}{N_t^{r,y}} = \frac{\zeta_t^e G_t^e}{N_t^{r,y}} = \frac{\zeta_t^e s_t^{g^e} N_t^f y_t^f}{N_t^{r,y}} = \frac{\zeta_t^e s_t^{g^e} n_t^f y_t^f}{n_t^{r,y}} \tag{C39}$$

$$g_t^{p,e} \equiv \frac{G_t^{p,e}}{N_t^{p,y}} = \frac{(1-\zeta_t^e)s_t^{g^e} N_t^f y_t^f}{N_t^{p,y}} = \frac{(1-\zeta_t^e)s_t^{g^e} n_t^f y_t^f}{n_t^{p,y}} \tag{C40}$$

$$g_t^{t,r,m} \equiv \frac{\zeta_t^t G_t^t}{N_t^{r,m}} = \frac{\zeta_t^t s_t^{g^t} N_t^f y_t^f}{N_t^{r,m}} = \frac{\zeta_t^t s_t^{g^t} n_t^f y_t^f}{n_t^{r,m}} \tag{C41}$$

$$g_t^{t,p,m} \equiv \frac{(1-\zeta_t^t)G_t^t}{N_t^{p,m}} = \frac{(1-\zeta_t^t)s_t^{g^t} N_t^f y_t^f}{N_t^{p,m}} = \frac{(1-\zeta_t^t)s_t^{g^t} n_t^f y_t^f}{n_t^{p,m}} \tag{C42}$$

$$s_t^{r,o} \equiv \frac{\zeta_t^s G_t^s}{N_t^{r,o}} = \frac{\zeta_t^s s_t^{g^s} N_t^f y_t^f}{N_t^{r,o}} = \frac{\zeta_t^s s_t^{g^s} n_t^f y_t^f}{n_t^{r,o}} \tag{C43}$$

$$s_t^{p,o} \equiv \frac{(1-\zeta_t^s)G_t^s}{N_t^{p,o}} = \frac{(1-\zeta_t^s)s_t^{g^s} N_t^f y_t^f}{N_t^{p,o}} = \frac{(1-\zeta_t^s)s_t^{g^s} n_t^f y_t^f}{n_t^{p,o}} \tag{C44}$$

This block gives 8 equations for the group-specific public spending items, $g_t^{r,h}$, $g_t^{p,h}$, $g_t^{r,e}$, $g_t^{p,e}$, $g_t^{t,r,m}$, $g_t^{t,p,m}$, $s_t^{r,o}$ and $s_t^{p,o}$.

Population fractions From Appendix A.3 above, we have:

$$n_t^{r,y} \equiv \frac{N_t^{r,y}}{N_t} = \frac{N_{t-1}}{N_t}[(1-\delta_r)x_{t-1}^r + \nu_r] \tag{C45}$$

$$n_t^{r,m} \equiv \frac{N_t^{r,m}}{N_t} = \frac{N_{t-1}}{N_t} n_{t-1}^{r,y} \tag{C46}$$

$$n_t^{r,o} \equiv \frac{N_t^{r,o}}{N_t} = \frac{N_{t-1}}{N_t} n_{t-1}^{r,m} \tag{C47}$$

$$n_t^{p,y} \equiv \frac{N_t^{p,y}}{N_t} = \frac{N_{t-1}}{N_t}[(1-\delta_p)x_{t-1}^p + \nu_p] \tag{C48}$$

$$n_t^{p,m} \equiv \frac{N_t^{p,m}}{N_t} = \frac{N_{t-1}}{N_t} n_{t-1}^{p,y} \tag{C49}$$

$$n_t^{p,o} \equiv \frac{N_t^{p,o}}{N_t} = \frac{N_{t-1}}{N_t} n_{t-1}^{p,m} \tag{C50}$$

$$\frac{N_t}{N_{t-1}} = 1 + \nu_r + \nu_p - n_{t-1}^{r,o} - n_{t-1}^{p,o} + (1-\delta_r)x_{t-1}^r + (1-\delta_p)x_{t-1}^p \tag{C51}$$

In this block, we have 7 equations in the above 7 variables. As said in Appendix A.3, we set $x^r_{t-1} \equiv n^{r,y}_{t-1}$ and $x^p_{t-1} \equiv n^{p,y}_{t-1}$.

Economy's resource constraint (which holds residually by Walras' law)

$$n^{r,y}_t c^{r,y}_t + n^{r,y}_t z^{r,y}_t + n^{r,m}_t c^{r,m}_t + n^{r,o}_t c^{r,o}_t + n^{p,y}_t c^{p,y}_t + n^{p,m}_t c^{p,m}_t + n^{p,o}_t c^{p,o}_t + n^{r,m}_t f^{r,m}_t + n^{r,m}_t \frac{x^f}{2}(f^{r,m}_t - f^{r,m})^2 +$$

$$+ \left(1 + r^d_t\right) \lambda^f_{t-1} \frac{N_{t-1}}{N_t} d_{t-1} + (1 + r^{eu}_t) \lambda^{eu}_{t-1} \frac{N_{t-1}}{N_t} d_{t-1} +$$

$$+ \left[n^{r,m}_t k^{r,m}_t - \left(1 - \delta^k\right) \frac{N_{t-1}}{N_t} n^{r,m}_{t-1} k^{r,m}_{t-1}\right] + \left(s^{g^h}_t + s^{g^e}_t + s^{g^i}_t + s^{g^c}_t\right) n^f_t y^f_t = n^f_t y^f_t + (1 + r^*_t) \frac{N_{t-1}}{N_t} n^{r,m}_{t-1} f^{r,m}_{t-1} +$$

$$+ \lambda^f_t d_t + \lambda^{eu}_t d_t$$

Appendix D: A fully funded (FF) public pension system

This appendix models the case in which the government collects the SSCs paid by employees/adults at each time t, invests them, say, in physical capital which earns the market return $(1 - \delta^k + r^k_{t+1})$ at $t + 1$ and then distributes the resulting amount to the same individuals when they reach the old age at $t + 1$. Thus, here we consider the best possible case where all related funds are invested in capital and the system is fully funded (see also Acemoglu (2009, chapter 9.5)).

We will model what changes only relative to above.

Now there are two separate government budget constraints:

$$[s^{g^h}_t + s^{g^e}_t + s^{g^t}_t + s^{g^w}_t + s^{g^i}_t + s^{g^c}_t] n^f_t y^f_t + \left(1 + r^d_t\right) (\lambda^d_{t-1} + \lambda^f_{t-1}) \frac{N_{t-1}}{N_t} d_{t-1} + (1 + r^{eu}_t) \lambda^{eu}_{t-1} \frac{N_{t-1}}{N_t} d_{t-1} +$$

$$+ \tau^s_{t-1} [n^{r,m}_{t-1} w^r_{t-1} l^{r,m}_{t-1} h^{r,m}_{t-1} + n^{p,m}_{t-1} w^p_{t-1} l^{p,m}_{t-1} h^{p,m}_{t-1}] \frac{N_{t-1}}{N_t} = d_t + \frac{T_t}{N_t} \tag{D1}$$

and

$$s_t = (1 - \delta^k + r^k_t) \tau^s_{t-1} [n^{r,m}_{t-1} w^r_{t-1} l^{r,m}_{t-1} h^{r,m}_{t-1} + n^{p,m}_{t-1} w^p_{t-1} l^{p,m}_{t-1} h^{p,m}_{t-1}] \frac{N_{t-1}}{N_t} \tag{D2}$$

where s_t denotes per capita public spending on pensions and the term $\tau_{t-1}^s[n_{t-1}^{r,m}w_{t-1}^r l_{t-1}^{r,m}h_{t-1}^{r,m}+n_{t-1}^{p,m}w_{t-1}^p l_{t-1}^{p,m}h_{t-1}^{p,m}]\frac{N_{t-1}}{N_t}$ is social security taxes paid by employees in the previous period and invested in capital in the previous period.

Furthermore, to make the two social security systems comparable in terms of fiscal size, we assume that:

$$s_t = s_t^{g^s} n_t^f y_t^f \tag{D3}$$

where $s_t^{g^s}$ is set equal to the value we used in the baseline PAYG model.

Algebraically, the above three equations are associated with solutions for the paths of d_t, s_t and τ_t^s.

The market-clearing condition in the capital market is now (since the social security funds paid by employees in the previous period were invested in capital and so are used by the firm in the current period):

$$n_t^f k_t^f = \frac{N_{t-1}}{N_t} n_{t-1}^{r,m} k_{t-1}^{r,m} + \tau_{t-1}^s [n_{t-1}^{r,m} w_{t-1}^r l_{t-1}^{r,m} h_{t-1}^{r,m} + n_{t-1}^{p,m} w_{t-1}^p l_{t-1}^{p,m} h_{t-1}^{p,m}] \frac{N_{t-1}}{N_t} \tag{D4}$$

Also notice that now the pensions received by each rich old and each rich poor person change to:

$$s_t^{r,o} \equiv \frac{\zeta_t^s s_t}{n_t^{r,o}} \tag{D5}$$

$$s_t^{p,o} \equiv \frac{(1-\zeta_t^s) s_t}{n_t^{p,o}} \tag{D6}$$

and that the per capita tax revenue changes to:

$$\frac{T_t}{N_t} \equiv \tau_t^c (n_t^{r,y} c_t^{r,y} + n_t^{r,m} c_t^{r,m} + n_t^{r,o} c_t^{r,o} + n_t^{p,y} c_t^{p,y} + n_t^{p,m} c_t^{p,m} + n_t^{p,o} c_t^{p,o}) +$$

$$+(\tau_t^n + \tau_t^s) n_t^{r,m} w_t^r l_t^{r,m} h_t^{r,m} + (\tau_t^n + \tau_t^s) n_t^{p,m} w_t^p l_t^{p,m} h_t^{p,m} + \tau_t^k \frac{N_{t-1}}{N_t} n_{t-1}^{r,m} (r_t k_{t-1}^{r,m} + \pi_t^{r,o}) +$$

$$+\tau_t^b n_t^{r,y} b_{t-1}^{r,y} + \tau_t^f n_t^f \left(y_t^f - w_t^r l_t^{r,f} - w_t^p l_t^{p,f} \right) \tag{D7}$$