Macroeconomic Dynamics, **26**, 2022, 1–48. Printed in the United States of America.
doi:10.1017/S1365100520000036

ON THE MIX OF GOVERNMENT EXPENDITURE AND TAX REVENUES

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We study the implications of changes in the mix of taxes, public spending, and public finance in the Eurozone. In so doing, we build a general equilibrium OLG model that naturally incorporates all the main categories of public spending and taxes. We focus on the medium- and long-run implications of permanent reforms in the actual policy mix. When we depart from 2008, the best way out of the recession would be an increase in public spending on education and health and in turn cuts in distorting taxes including social security contributions. When we depart from the year 2017, which features a higher inherited public debt, public debt consolidation becomes the superior reform to the extent that the focus is on the medium and long run.

Keywords: Fiscal Reforms, Public Finance

1. INTRODUCTION

European Union (EU) policymakers have repeatedly stressed the need to reconsider the composition of public spending and taxes so as to move the economy to more efficient and, perhaps, more egalitarian outcomes.[1] In this paper, we revisit this classic issue. Namely, we study how permanent changes in the tax spending–public finance policy mix would affect private incentives and the macroeconomy in the medium and long term. The point of departure is the policy mix in the

We thank the Associate Editor and two referees for constructive suggestions and criticisms. We also thank Kostas Angelopoulos, David de la Croix, Saqib Jafarey, Jim Malley, Vassilis Monastiriotis, and Waltraud Schelkle for comments and discussions. We have benefited from discussions with Harris Dellas, Vangelis Dioikitopoulos, Dimitris Papageorgiou, Rana Sajedi, and Petros Varthalitis, as well as from comments by seminar participants at the Research Workshop in European Studies at the European Institute of the LSE. Any errors are ours. Stelios Sakkas wishes to clarify that the views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission. Address correspondence to: Apostolis Philippopoulos, Department of Economics, Athens University of Economics and Business, 76 Patission street, Athens 10434, Greece, Phone: +30-210-8203357; e-mail: aphil@aueb.gr

 1469-8056/20

Eurozone as it was when the world crisis erupted in 2008 and as it is in the current situation.

We include all the main categories of public spending and tax revenues in a unified general equilibrium framework. On the spending side, we distinguish among spending on social protection, health, education, economic affairs (e.g. infrastructure), defense, public order and safety, general public services, etc.; these are the most important functional categories of spending in the data (see). On the taxation side, we distinguish among personal (labor and capital) income taxes, corporate income taxes, indirect taxes, and social security contributions paid by employers and employees; these are the most important types of taxes in the data (see).[2]

The vehicle of our analysis is a general equilibrium OLG model that includes all the above categories of spending and taxes. More importantly, our model accommodates these categories in a natural way.[3] For instance, public spending on health increases the probability of reaching the old age and can also enhance individual human capital, public spending on education contributes to the accumulation of individual human capital of younger generations, public spending on economic affairs improves infrastructure and benefits the productivity of firms, public spending on social protection provides pensions to the old, public spending on defense, and public-order safety can protect firms' property rights, etc. The same applies to taxes. For instance, households pay capital and labor taxes as well as social security contributions. Also, firms pay corporate taxes and social security contributions. Social security contributions finance (partially or fully) a pay-as-you-go (PAYG) public pension system.

The constructed model is solved numerically using conventional parameter values and data from the Eurozone.[4] Departing from this solution, we will study the implications of various hypothetical reforms. By reforms, we mean *ad hoc* permanent changes in the tax spending–public finance mix. The comparison of alternative policies will be in terms of discounted lifetime output and utility, so that the focus will be on the medium- and long-term implications of reforms.[5] In our experiments, we will first depart from the year 2008 and in turn from the year 2017. The former will allow us to provide a quantitative assessment of policy scenarios since the eruption of the 2008 crisis that, if they had been implemented, they could possibly have made the downturn milder. The latter can help us to investigate what can happen from now onward in the era of high public debt (the year 2017 was the last year of the expansion phase, 2013–2017, that followed the Great Recession; also, data beyond 2017 are not yet fully available).

Our main results are as follows. When we depart from the 2008 solution, increases in public spending on education and health and, in turn, cuts in distorting taxes (on personal labor income, social security contributions paid by employers and employees, and personal capital income) systematically outscore the *status quo* as well as other expansionary policies meaning other spending rises and tax cuts. This happens mainly because these policies stimulate private savings and this is good for capital accumulation and consumption over time. These beneficial effects of increases in productive public spending and/or cuts in distorting taxes are stronger when financed by temporary rises in public debt. By contrast, an increase in spending on public pensions (which is the main item of social protection) is found to be particularly bad. Such an increase distorts private incentives to save and this hurts output and welfare over time.This is a known result. See, for example, the report of ECB (2017). Interestingly, a rise in spending on public pensions hurts even those who are supposed to be the main beneficiaries, namely, the old households. This happens because the indirect aggregate harm (from lower private savings and a smaller GDP) more than outweighs any direct benefits (from the policy attempt to allocate more social resources to pensions).

When we depart from the 2017 solution, a distinct feature of which is the high inherited public debt relative to 2008, the above results continue to hold but now a new fiscal reform comes at the top both in terms of lifetime output and lifetime utility: public debt consolidation. This happens because public debt consolidation produces a strong crowding in capital and this proves to be particularly beneficial to the macroeconomy over the medium and long run. These beneficial effects of debt consolidation in the medium and long run get stronger when we allow a distorting tax rate to take advantage of the fiscal space created once the debt burden has been reduced; it is the anticipation of these cuts that stimulates the economy along its transition path to a new solution with a lower debt burden.

It is worth stressing that these results are robust to several changes in the model including the choice of the residually determined public financing instrument (namely, which fiscal variable adjusts to close the government budget constraint once a reform takes place); the addition of demographic problems such as ageing and underbirth; the role of private spending on education; and the exact type of the public pension system, etc. A special reference should be made however to the role of public spending on defense and public-order safety: once we assume institutional problems as those observed in several South European countries,[6] and, at the same time, allow this type of public spending to help in the protection of property rights, its desirability rises.

The rest of the paper is organized as follows. Section 2 reports Eurozone data. The baseline model is developed in Section 3. Section 4 presents parameter values and the fiscal data used in the solutions. Fiscal reforms are defined in Section 5. Sections 6 and 7 report results when we depart from 2008 and 2017, respectively. A sensitivity analysis is in Section 8. Section 9 closes the paper. Algebraic details, tables, and figures are given in an Appendix.

2. MIX OF PUBLIC EXPENDITURES AND TAX REVENUES IN THE EUROZONE

Table 1 describes some key characteristics of fiscal policy in the Eurozone. Specifically, Table 1a presents public spending data according to their function, while Table 1b presents the main types of tax revenues. In these tables, we present data averages prior to the world crisis (2001–2008) as well as after the crisis

https://doi.org/10.1017/S1365100520000036 Published online by Cambridge University Press

TABLE 1a. Structure of public spending in the Eurozone

Type of spending	2001–08 % of GDP	2001–08 % of total public spending	2013–17 % of GDP	2013–17 % of total public spending
Social protection	18.10	38.60	20.10	41.35
Health	6.60	14.10	7.20	14.80
General public services	7.20	15.40	6.80	14.00
Education	4.70	10.00	4.70	9.67
Economic affairs	4.50	9.60	4.40	9.05
Public order and safety	1.70	3.65	1.70	3.49
Defense	1.30	2.77	1.20	2.46
Environmental protection	0.80	1.70	0.80	1.65
Housing and community amenities	0.80	1.70	0.60	1.23
Recreation and culture	1.10	2.35	1.10	2.26
Total	46.8		48.6	

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

TABLE 1b. Structure of tax revenues in the Eurozone

Type of tax	2001–08 % of GDP	2001–08 % of total tax revenues	2013–17 % of GDP	2013–17 % of total tax revenues
SSC (Employers)	7.80	0.21	8.00	0.212
SSC (Employees)	5.80	0.156	6.20	0.165
Consumption	10.40	0.28	10.80	0.287
Labour income (excluding SSC)	4.30	0.116	4.40	0.117
Capital income (non-corporate)	5.80	0.156	5.50	0.146
Capital income (corporate)	2.90	0.078	2.60	0.070
Total	37.00		37.60	

Notes: (i) Source: European Commission, Taxation Trends in the EU; authors' 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.

(2013–2017). Note that the year 2013 was the first year of macroeconomic recovery so we prefer to omit the in between years of turmoil, 2009–2012. Also, as said above, as this paper is written, most of these data are not available beyond 2017.

Some clarifications are helpful for the understanding of the model developed in the next sections. On the spending side, we have public spending on social protection (which includes spending on pensions, family support, unemployment benefits, housing, sickness, and disability, etc.), public spending on health (which includes public health, medical products and equipment, hospital services, outpatient services, etc.), public spending on general public services (which includes public debt payments, administrative spending, foreign economic aid, executive and legislative organs, fiscal affairs, and other transfers of a general character between different levels of government), public spending on education (which includes spending on pre-primary and primary education, secondary and post secondary, non-higher and higher education), public spending on economic affairs (which includes public infrastructure spending such as public transport, fuel and energy, mining, manufacturing and construction, communications, licenses, and other related support programs), and public spending on public-order safety and defense (which includes military defense, civil defense, foreign military aid, police and fire protection services, law courts, and prisons, etc.). Other minor (quantitatively) types of spending are on environmental protection, housing and community amenities, and recreation and culture. On the revenue side, there are direct taxes on personal income from labor and capital, as well as corporate income taxes on firms' profits, while the main indirect taxes are taxes on sales, value-added, or imported goods (indirect taxes are labeled as consumption taxes in Table 1b and throughout the paper). Also, although there are differences across countries, for the average of the Eurozone, an important share of tax revenues comes from social security contributions.[7]

As can be seen, public spending on social protection is the biggest spending item in the data, being followed by spending on health and general public services and, in turn, by spending on education and economic affairs. Comparing pre-crisis and post-crisis numbers, spending on social protection has risen in the post-crisis years, while spending on general public services has fallen (perhaps because of a reduction in interest payment on public debt), while the rest have remained more or less unchanged. Regarding taxes, the main revenues come from consumption taxes and personal (labor plus capital) income taxes. Social security contributions paid by employers contribute more than those paid by employees. There are small changes in this tax structure over time.

In what follows, we will develop a model that gives a natural role to most of these spending and tax categories.

3. AN OLG MODEL

Consider a closed economy populated by overlapping generations of three-period-lived households, private firms, and the government.[8] In each period t, there are N_t^y young members, N_t^m adult members, and N_t^o old members. Thus, the total population is $N_t^y + N_t^m + N_t^o = N_t$ at t. Assume that the number of agents in each generation grows at a constant rate, n, so that the size of the newly born generation at t is $N_t^y = (1+n)N_{t-1}^y = (1+n)^t N_0^y$, where the initial N_0^y is given. There are also N_t^f private firms owned by adults in each period t. In order to finance its various categories of spending, the government levies distorting taxes, and issues bonds. Time is discrete and infinite.

3.1. Households

Each individual can live for three periods, as young, adult, and old. He consumes in each period. A young individual starts with his parents' bequest and spends effort time and funds in education. When he is adult, he works and saves in the form of capital and government bonds. When he reaches the old age, which happens with probability $0 \leq q_t \leq 1$, he uses his own savings and social security (namely, a public pension) and dies leaving an optimally chosen bequest. With probability $0 \leq 1 - q_t \leq 1$, he dies before reaching the old age leaving an unintended bequest. These bequests (chosen and unintended) are inherited by the newly born young people.

This means that at time t there are $(1+n)^t N_0^y = N_t^y$ newly born young people, $(1+n)^{t-1} N_0^m = N_t^m$ adult people born at $t-1$, and $q_t(1+n)^{t-2} N_0^o = N_t^o$ old people born at $t-2$ and surviving today with probability q_t. Hence, at any time t, the population fractions of young, adult, and old people are, respectively, $n_t^y \equiv \frac{N_t^y}{N_t^y + N_t^m + N_t^o} = \frac{(1+n)^2}{(1+n)^2 + (1+n) + q_t}$, $n_t^m \equiv \frac{N_t^m}{N_t^y + N_t^m + N_t^o} = \frac{(1+n)}{(1+n)^2 + (1+n) + q_t}$ and $n_t^o \equiv \frac{N_t^o}{N_t^y + N_t^m + N_t^o} = \frac{q_t}{(1+n)^2 + (1+n) + q_t}$, while the gross rate of change in total population between two periods is $\frac{N_t}{N_{t-1}} = (1+n)\left(\frac{(1+n)^2 + (1+n) + q_t}{(1+n)^2 + (1+n) + q_{t-1}}\right)$.

3.1.1. Household's utility function. The objective of each household born at t is to maximize discounted lifetime utility defined as:

$$u_t = \frac{(c_t^y)^{1-\sigma}}{1-\sigma} - \chi_n \frac{(e_t^y)^{1+\eta}}{1+\eta} + \chi_g \frac{(g_t^u)^{1-\zeta}}{1-\zeta} + \\ + \beta \left\{ \frac{(c_{t+1}^m)^{1-\sigma}}{1-\sigma} - \chi_n \frac{(l_{t+1}^m)^{1+\eta}}{1+\eta} + \chi_g \frac{(g_{t+1}^u)^{1-\zeta}}{1-\zeta} \right\} \\ + \beta^2 q_{t+2} \left\{ \frac{(c_{t+2}^o)^{1-\sigma}}{1-\sigma} + \chi_g \frac{(g_{t+2}^u)^{1-\zeta}}{1-\zeta} + \beta \chi_b \frac{(b_{t+2}^o)^{1-\xi}}{1-\xi} \right\}, \quad (1)$$

where c_t^y, c_{t+1}^m, c_{t+2}^o are consumptions when young, adult, and old, respectively; e_t^y is the effort time spent in education when young; l_{t+1}^m is the effort time spent in work when adult; $g_t^u \equiv \frac{G_t^u}{N_t}$ denotes per capita public spending on "utility-enhancing" public goods and services (see Subsection 3.3.3 for the definition of utility-enhancing public goods and services); and b_{t+2}^o is a bequest chosen by the old [the way we model the bequest motive is as follows: for example, Acemoglu (2009, Chapter 9.6) and Coeurdacier et al. (2015)]. The parameter $0 < \beta < 1$ is the subjective time preference rate and σ, η, ζ, χ_n, χ_g, χ_b, ξ are standard preference parameters. As said above, $0 \leq q_{t+2} \leq 1$ is the probability of someone born today to reach the old age after two periods.

3.1.2. Household's budget constraints and bequests. The budget constraints of the household when young, adult, and old are, respectively:

$$\left(1+\tau_t^c\right) c_t^y + z_t^y = \left(1-\tau_t^b\right) b_{t-1,}^y \tag{2}$$

$$\left(1+\tau_{t+1}^c\right) c_{t+1}^m + k_{t+1}^m + d_{t+1}^m = \left(1-\tau_{t+1}^n-\phi_{t+1}\right) w_{t+1} h_{t+1}^m l_{t+1,}^m \tag{3}$$

$$\begin{aligned}\left(1+\tau_{t+2}^c\right) c_{t+2}^o + b_{t+2}^o = &\left[1-\delta^k+\left(1-\tau_{t+2}^k\right) r_{t+2}\right] k_{t+1}^m + \left(1-\tau_{t+2}^k\right) \pi_{t+2}^o \\ &+ \left(1+\rho_{t+2}\right) d_{t+1}^m + s_{t+2,}^o\end{aligned} \tag{4}$$

where z_t^y is the private spending on education when young,[9] h_{t+1}^m is the stock of private human capital when adult (see below for its motion), w_{t+1} is the wage earned when adult, k_{t+1}^m is the savings in the form of physical capital, d_{t+1}^m is the savings in the form of government bonds, r_{t+2} is the return to physical capital, ρ_{t+2} is the return to government bonds, π_{t+2}^o is the dividends received from firms, s_{t+2}^o is the pension given to each surviving old person from the government, and b_{t-1}^y is an initial endowment which is taken as given by the household (nevertheless, in equilibrium, b_{t-1}^y will be proportional to what is left by the older generations—see below).[10] Finally, $0 \leq \tau_t^c$, τ_t^k, $\tau_t^b < 1$ are tax rates on consumption, personal capital income, and bequests, respectively, while $0 \leq \tau_t^n < 1$ is the tax rate on the income earned from labor, and $0 \leq \phi_t < 1$ is the social security contribution paid by employees.[11] We will assume a PAYG system, as this is the case in most countries, according to which each currently old household receives a pension, s_t^o, and these social security benefits are (partially or fully) financed by current contributions paid by both employees and employers as well as by the general government budget (see below).

Equation (4) holds with probability $0 \leq q_{t+2} \leq 1$ only. With probability $0 \leq 1-q_{t+2} \leq 1$, the adult dies before reaching the old age. In the latter case, he leaves an enforced or unintended bequest, denoted as Ω_{t+2}^o. The enforced bequest when the adult dies before reaching the old age is his whole wealth, namely:

$$\Omega_{t+2}^o \equiv \left[1-\delta^k+\left(1-\tau_{t+2}^k\right) r_{t+2}\right] k_{t+1}^m + \left(1-\tau_{t+2}^k\right) \pi_{t+2}^o + \left(1+\rho_{t+2}\right) d_{t+1.}^m \tag{5}$$

Therefore, while the initial endowment inherited by the young, b_{t-1}^y, is taken as given when solving the optimization problem, in equilibrium, it will be a weighted average of the bequest voluntarily chosen by the old, b_{t+2}^o, and the enforced bequest, Ω_{t+2}^o, in case the adult dies suddenly before reaching the old age, where the weights are, respectively, the probability of reaching the old age, q_{t+2}, and the probability of suddenly passing away, $1-q_{t+2}$.[12] When the universe starts, b_{t-1}^y is an initial condition.

3.1.3. Household's human capital. The motion of household's human capital is defined as:[13]

$$h_{t+1}^m = \left(1-\delta^h\right) h_t^y + B\left(e_t^y\right)^\theta \left[\gamma\left(z_t^y\right)^\nu + (1-\gamma)\left(\bar{G}_t^e + \lambda \bar{G}_t^h\right)^\nu\right]^{\frac{1-\theta}{\nu}}. \tag{6}$$

https://doi.org/10.1017/S1365100520000036 Published online by Cambridge University Press

In other words, individual human capital is augmented by effort time spent in school, e_t^y, by private spending on education, z_t^y, and by government spending per young person allocated to education, $\bar{G}_t^e \equiv \frac{G_t^e}{N_t^y}$, and to health, $\bar{G}_t^h \equiv \frac{G_t^h}{N_t^y}$, where the parameter $0 \leq \lambda \leq 1$ measures how much public spending on health contributes to the quality of human capital (unhealthy people cannot be efficient, irrespectively of their education level).[14] Also, $B > 0$, $0 \leq \theta \leq 1$, $0 \leq \gamma \leq 1$, and $0 \leq \nu \leq 1$ are parameters. The idea behind this functional form is that effort time in school is combined, through a Cobb–Douglas technology, with total (private and public) education spending, with weights θ and $1-\theta$, respectively, to augment private human capital. In turn, private and public education spending, with weights γ and $1-\gamma$, respectively, are combined into an aggregate through a CES technology with an elasticity of substitution $1/(1-\nu)$.[15] Finally, $B > 0$ is a scale parameter.

3.1.4. The probability of reaching the old age. For simplicity, we assume that the probability of an adult reaching the old age, q_t, depends only on current public spending on health as a fraction of GDP. This is denoted as $q_t \equiv q(\frac{G_t^h}{N_t^f y}) \equiv q(s_t^{g^h})$, where $q\,(.)$ is increasing and concave.[16] For convenience, we will use the functional form:

$$q_t \equiv \Xi \left(1 + \frac{s_t^{g^h}}{1 + s_t^{g^h}}\right), \qquad (7)$$

where the parameter $0 < \Xi < 1$ will be calibrated so as the probability to be within usual ranges [see also e.g. Chakraborty (2004) and Dioikitopoulos (2014)].

3.1.5. Household's optimality conditions. Households act competitively taking prices, policy instruments, and aggregate outcomes as given. They solve their problem at the start of their lives. Thus, they choose c_t^y, c_{t+1}^m, c_{t+2}^o, e_t^y, z_t^y, l_{t+1}^m, k_{t+1}^m, d_{t+1}^m, b_{t+2}^o subject to their budget constraints and the motion of their human capital.[17] The first-order conditions include these constraints and also the optimality conditions for e_t^y, z_t^y, l_{t+1}^m, k_{t+1}^m, d_{t+1}^m, and b_{t+2}^o, respectively:

$$\chi_n \left(e_t^y\right)^\eta = \frac{\beta \left(c_{t+1}^m\right)^{-\sigma} \left(1 - \tau_{t+1}^n - \phi_{t+1}\right) w_{t+1} l_{t+1}^m B\theta \left(e_t^y\right)^{\theta-1} \left[\gamma \left(z_t^y\right)^\nu + (1-\gamma)\left(\bar{G}_t^e + \lambda \bar{G}_t^h\right)^\nu\right]^{\frac{1-\theta}{\nu}}}{\left(1 + \tau_{t+1}^c\right)}, \qquad (8)$$

$$\frac{\left(c_t^y\right)^{-\sigma}}{\left(1 + \tau_t^c\right)} = \frac{\beta \left(c_{t+1}^m\right)^{-\sigma} \left(1 - \tau_{t+1}^n - \phi_{t+1}\right) w_{t+1} l_{t+1}^m B \left(e_t^y\right)^\theta \gamma (1-\theta) \left[\gamma \left(z_t^y\right)^\nu + (1-\gamma)\left(\bar{G}_t^e + \lambda \bar{G}_t^h\right)^\nu\right]^{\frac{1-\theta}{\nu}-1}}{\left(z_t^y\right)^{1-\nu} \left(1 + \tau_{t+1}^c\right)}, \qquad (9)$$

$$\chi_n \left(l_{t+1}^m\right)^\eta = \frac{\left(c_{t+1}^m\right)^{-\sigma} \left(1 - \tau_{t+1}^n - \phi_{t+1}\right) w_{t+1} h_{t+1}^m}{\left(1 + \tau_{t+1}^c\right)}, \qquad (10)$$

$$\frac{\left(c_{t+1}^{m}\right)^{-\sigma}}{\left(1+\tau_{t+1}^{c}\right)}=\frac{\beta q_{t+2}\left(c_{t+2}^{o}\right)^{-\sigma}\left[\left(1-\delta^{k}\right)+\left(1-\tau_{t+2}^{k}\right)r_{t+2}\right]}{\left(1+\tau_{t+2}^{c}\right)}, \tag{11}$$

$$\frac{\left(c_{t+1}^{m}\right)^{-\sigma}}{\left(1+\tau_{t+1}^{c}\right)}=\frac{\beta q_{t+2}\left(c_{t+2}^{o}\right)^{-\sigma}\left(1+\rho_{t+2}\right)}{\left(1+\tau_{t+2}^{c}\right)}, \tag{12}$$

$$\frac{\left(c_{t+2}^{o}\right)^{-\sigma}}{\left(1+\tau_{t+2}^{c}\right)}=\beta\chi_{b}\left(b_{t+2}^{o}\right)^{-\xi}. \tag{13}$$

3.2. Private Firms

There are $f=1,2,...,N_t^f$ firms. Firms act competitively taking prices, policy instruments, and aggregate outcomes as given. Thus, each firm chooses its capital and labor inputs, denoted as k_t^f and l_t^f, to maximize net profits given by:

$$\pi_t^f \equiv y_t^f-(1+\phi_t^f)w_t l_t^f-r_t k_t^f-\tau_t^f(y_t^f-w_t l_t^f), \tag{14}$$

where y_t^f is the firm's output, ϕ_t^f is the social security contribution paid by firms/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 [see e.g. Turnovsky (1995, Chapter 10)]. Notice that our modeling allows for double taxation on capital, since households also pay taxes on their personal capital income; however, capital's double taxation is a usual phenomenon in several countries, and, in any case, we report that our results are not sensitive to whether we have double taxation or not.

Output, y_t^f, is produced by the function [see e.g. Lansing (1998)]:

$$y_t^f=A\left(k_t^f\right)^{\alpha_1}\left(l_t^f\right)^{\alpha_2}\left(\frac{K_t^g}{N_t^f}\right)^{1-\alpha_1-\alpha_2}, \tag{15}$$

where K_t^g is the total stock of public capital (see below for its motion) and $A>0$, $0<\alpha_1,\alpha_2<1$ are technology parameters.

The first-order conditions for private inputs, k_t^f and l_t^f, are:

$$r_t=\frac{(1-\tau_t^f)\,\alpha_1 y_t^f}{k_t^f}, \tag{16}$$

$$(1+\phi_t^f-\tau_t^f)w_t=\frac{(1-\tau_t^f)\,\alpha_2 y_t^f}{l_t^f}, \tag{17}$$

so that each firm's net profit is:

$$\pi_t^f=(1-\tau_t^f)(1-\alpha_1-\alpha_2)y_t^f. \tag{18}$$

https://doi.org/10.1017/S1365100520000036 Published online by Cambridge University Press

3.3. Government

On the revenue side, the government uses personal capital income taxes, τ_t^k, personal labor income taxes, τ_t^n, consumption taxes, τ_t^c, corporate income taxes, τ_t^f, social security contributions paid by workers and firms, ϕ_t and ϕ_t^f, respectively, as well as taxes on bequests, τ_t^b. There can also be revenues from the issuance of bonds, where D_{t+1} denotes the end-of-period total stock of one-period maturity bonds issued by the government. On the expenditure side, in our model, we have public spending on health, G_t^h, education, G_t^e, infrastructure, G_t^i, defense and public-order safety, G_t^d, pensions, G_t^s, as well as public spending on the rest of government activities denoted as G_t^c (see below for the categories included in G_t^c).

3.3.1. An entirely self-financed public pension system. It is convenient for expositional reasons to present first the special, but popular in the academic literature, case in which the public pension system operates separately with its own budget constraint [see e.g. Soares (2006), Conesa and Garriga (2008), and Bruce and Turnovsky (2013)]. Thus, there is a general government budget constraint as well as a separate social security budget constraint, where the latter is balanced in each period. In this case, according to a PAYG system,[18] total social security benefits, $G_t^s = N_t^o s_t^o$, are fully financed by social security contributions paid by workers, $\phi_t N_t^m w_t l_t^m h_t^m$, and firms, $\phi_t^f N_t^f w_t l_t^f$, all of which refer to the current time period. Thus, in each period, the self-financed budget constraint of the PAYG system is:

$$G_t^s = N_t^o s_t^o = \phi_t N_t^m w_t l_t^m h_t^m + \phi_t^f N_t^f w_t l_t^f. \tag{19}$$

Then, the general government budget constraint includes all other types of spending and revenues, namely,

$$G_t^h + G_t^e + G_t^i + G_t^d + G_t^c + (1 + \rho_t) D_t = D_{t+1} + T_t, \tag{20}$$

where T_t is tax revenues from all sources, except social security contributions, defined here as:

$$\begin{aligned} T_t \equiv\ & \tau_t^c \left(N_t^y c_t^y + N_t^m c_t^m + N_t^o c_t^o\right) + \tau_t^n N_t^m w_t l_t^m h_t^m + \tau_t^k N_{t-1}^m \left(r_t k_{t-1}^m + \pi_t^o\right) \\ & + \tau_t^b N_t^y b_{t-1}^y + \tau_t^f N_t^f (y_t^f - w_t l_t^f). \end{aligned} \tag{21}$$

Note that, in this case, there are two policy instruments that are residually determined, one to satisfy equation (19) and another one to satisfy equation (20). When we work with this special case, we will choose, at least in the baseline scenario, those instruments to be, respectively, the SSC paid by employees, ϕ_t, and the end-of-period public debt, D_{t+1} (see Section 5 for other public financing scenaria).

3.3.2. Consolidated government budget constraint. In the more general case, public spending on pensions, G_t^s, can differ from the associated social security contributions earmarked for its financing. When the public pension budget is not balanced, any difference between G_t^s and social security contributions is financed out of the general budget. Thus, we now have the consolidated government budget constraint:

https://doi.org/10.1017/S1365100520000036 Published online by Cambridge University Press

$$G_t^h + G_t^e + G_t^i + G_t^d + G_t^c + [G_t^s - \phi_t N_t^m w_t l_t^m h_t^m - \phi_t^f N_t^f w_t l_t^f] \\ + (1+\rho_t) D_t = D_{t+1} + T_t. \tag{22}$$

Note that, in this case, only one policy instrument needs to be residually determined. Following usual practice in the literature, we will assume, at least in the baseline scenario, that this role is played by D_{t+1} (see Section 5 for other public financing scenario).

Finally, for convenience, concerning the public spending instruments, G_t^h, G_t^e, G_t^i, G_t^d, G_t^s, and G_t^c, we will work in terms of their GDP shares defined, respectively, as $s_t^{g^h} \equiv \frac{G_t^h}{N_t^f y_t^f}$, $s_t^{g^e} \equiv \frac{G_t^e}{N_t^f y_t^f}$, $s_t^{g^i} \equiv \frac{G_t^i}{N_t^f y_t^f}$, $s_t^{g^d} \equiv \frac{G_t^d}{N_t^f y_t^f}$, $s_t^{g^s} \equiv \frac{G_t^s}{N_t^f y_t^f}$, and $s_t^{g^c} \equiv \frac{G_t^c}{N_t^f y_t^f}$.

3.3.3. The role of public spending in our model. The economic role of $s_t^{g^h}$, $s_t^{g^e}$, $s_t^{g^i}$, $s_t^{g^d}$, and $s_t^{g^s}$ is straightforward, and their values can be set as in the data. Regarding G_t^c (or its output share, $s_t^{g^c}$), which includes the rest of public spending, it is defined as the public spending on general public services net of debt payments (recall that spending on debt payments is already captured by $\rho_t D_t$ in our model), plus public spending on housing and community amenities, recreation, culture, and environmental protection, plus public spending on social security net of pensions (recall that spending on pensions is already included in our model); these are the rest of government activities in the data (see Table 1a).

Following usual practice [see e.g. European Central Bank, 2009], we will treat the sum of G_t^c and G_t^d as utility-enhancing public activities, or as "pure public goods," entering directly the household's utility function (1); thus, we assume $G_t^u \equiv G_t^c + G_t^d$ in equation (1). We report, however, that when we simply use $G_t^u \equiv G_t^c$, or when we also allow other categories of public spending (such as education) to be included in the definition for G_t^u, the main results are not affected, especially the results for output. In addition, in Section 8, we will allow public spending on defense and public-order safety, G_t^d, to play a more distinct role by also protecting property rights.

Finally, public investment spending on infrastructure, G_t^i, is used to augment public capital. Thus,

$$K_{t+1}^g = (1-\delta^g) K_t^g + G_t^i, \tag{23}$$

where $0 < \delta^g < 1$ is a depreciation parameter.

3.4. Macroeconomic Equilibrium

Collecting all the above equations, the equilibrium system is presented in Appendix A. It is a second-order dynamic system of 14 equations in 14 endogenous variables. The 14 endogenous variables are $\{z_t^y, c_t^y, c_t^m, c_t^o, e_t^y, l_t^m, k_t^m, \rho_t, h_t^m, s_t^o, \phi_t, d_t^m, b_t^o, k_{t+1}^g\}_{t=0}^{\infty}$. Notice that this is the system in the special case in which the public pension system is self-financed via adjustments in $\{\phi_t\}_{t=0}^{\infty}$. If this

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is not the case (meaning that there can be a difference between public spending on pensions and social security contributions to it and that this difference is financed out of the general budget), we use the consolidated government budget constraint only (see equation (22)), instead of two separate ones (see equations (19) and (20)), and we move ϕ_t to the list of the exogenously set policy variables. Details are provided in Appendix A.

3.5. How We Are Going to Work, Experiments, and Solution Methodology

In what follows, we work as follows. In Section 4, we present parameter values and data averages for fiscal (tax-spending) variables from the Eurozone. Using this, Sections 5–8 will solve the model numerically in order to investigate the aggregate and distributional implications of various hypothetical permanent reforms in the tax-spending-public finance policy mix; the reforms studied will be defined in Section 5. Specifically, in Section 6, we will first solve the model using data averages from the Eurozone prior to the crisis, 2001–2008, and then, departing from the resulting steady state solution defined as the *status quo* in 2008,[19] we will study the implications of the reforms in Section 5. This will allow us to search for policy scenarios since the eruption of the global crisis that, if they had been implemented, they could have made the downturn milder from 2009 onward. In Section 7, we will repeat the same exercise except that now we will solve the model using post crisis 2013–2017 data so that we will depart from the new steady-state solution defined as the *status quo* in 2017. This will allow us to investigate what could happen from 2018 onward.[20] Various robustness checks are given in Section 8.

In all experiments, the reference will be the associated *status quo* solution, namely, what would have happened if the policy variables had remained for ever as in the data at the time of departure. The systems will be solved using a Newton-type nonlinear method as implemented in DYNARE. Note that, since the model is kept deterministic, transition dynamics will be driven by hypothetical policy reforms only.

4. PARAMETERS AND DATA USED IN THE SOLUTIONS

Subsections 4.1 and 4.2 present, respectively, the parameter values and fiscal variables used in the solutions.

4.1. Parameter Values

Preference and technology parameters are listed in Table 2a. We use conventional values and also report that our main results are robust to changes in these values (details are provided in Section 8). Thus, although our numerical simulations below are not meant to provide a rigorous quantitative study, they illustrate the qualitative dynamic features of the model in a robust way.

TABLE 2a. Baseline parameterization

Parameters	Value	Description
β	0.985^{25}	Time preference rate
σ	1	Elasticity of intertemporal substitution
χ_n	7	Preference parameter related to effort time
χ_b	1	Preference parameter related to bequests
χ_g	0.100	Preference parameter related to public spending
ζ	1	Elasticity of public consumption in utility
η	1	Inverse of Frisch labour supply elasticity
ξ	1	Elasticity of bequests in utility
Ξ	0.600	Parameter in the probability of reaching the old age
Γ	0.800	Parameter in the degree of protection of property rights
A	2	Scale parameter in production of goods
α_1	0.350	Share of capital in production
α_2	0.600	Share of labour in production
B	15	Scale parameter in production of human capital
θ	0.750	Productivity of education time
λ	0.500	Contribution of public spending on health in human capital
ν	0.500	Elasticity parameter in human capital
γ	0.250	Weight to private spending in human capital
δ^k	1	Physical capital depreciation rate
δ^h	1	Human capital depreciation rate
δ^g	1	Public capital depreciation rate
n	0, −0.02	Population growth rate

The time unit is meant to be a period consisting of 25 years. Regarding preference parameters, we use values used by most of the related OLG literature. The time preference rate, β, is set at 0.985^{25} so as to be consistent with a value for the real interest rate around 5% per year. The weights given to public goods and bequests in household's utility function, χ_g and χ_b, are initially set at 0.1 and 1, respectively. The elasticity of intertemporal substitution, σ, the inverse of Frisch labor elasticity, η, and the elasticity of bequests in the utility function, ξ, are set as in related studies. The preference parameter related to effort time, χ_n, is set at 7, which gives hours of work within usual ranges.

Regarding technology parameters in the production function of goods (see equation (15)), the Cobb–Douglas exponents of physical capital and labor are set at 0.35 and 0.60, respectively, so that the exponent of public capital is 0.05 (the latter is close to public investment as share of output). The scale parameter in the same function, A, is set at 2. As is usual in the OLG literature, we set the values of the depreciation rates of physical, human, and public capital equal to 1. We start with zero population growth, $n = 0$ (however, see Subsection 7.3 for other values). In the human capital production function (see equation (6)), the values of B and θ are close to the values used by the growth literature; these parameter values imply hours of education within usual ranges. Following Stokey (1996), the

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elasticity parameter, ν, is set at the neutral value of 0.5 (this implies $1/(1-\nu)=2$ so that private and public education spending are good substitutes). The weight given to private vis-a-vis public spending in the same function, γ, is set at 0.25; this implies that, in equilibrium, private education spending as share of GDP is around 0.5%, which is as in the European data (see Section 8 for sensitivity). In regard to the parameter $0<\lambda\leq 1$ measuring the contribution of public spending on health in the creation of human capital, we set it at the relatively neutral value of 0.5 (again, see Section 8 for sensitivity).

4.2. Fiscal Policy Data Used in the Solutions

We use data from the Eurozone. Most of the data are from Eurostat. Regarding public spending, 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 (see European Commission, 2013), which is comprised by the functional categories listed in Table 1a. To solve our model, we need data on education, health, defense and public-order safety, old age pensions and survivors (the latter is the main subcategory of social protection expenditure in Table 1a), and infrastructure (this is part of spending on economic affairs in Table 1a). The averages values of these spending items as shares of GDP ($s_t^{g^e}$, $s_t^{g^h}$, $s_t^{g^d}$, $s_t^{g^s}$, $s_t^{g^i}$) over 2001–2008 and over 2013–2017 are presented in Table 2b. The rest of spending items are included in s^{g^c}, as defined in Subsection 3.3.3.

The tax rates on consumption, capital income, labor income, and profits (τ^c, τ^k, τ^n, and τ^f) are the average values of the effective tax rates in the Eurozone [the source is European Commission (2014b, 2018b), or they have been constructed by us applying the same (Mendoza-Razin-Tesar) methodology by using Eurostat data]. Note that the value of the labor tax rate, τ^n, does not include the social security contributions, ϕ and ϕ^f, paid by workers and employers, respectively. Setting s^{g^s} and ϕ^f at their data average values, the value of ϕ that follows residually from the PAYG budget constraint is close to its average value in the data and the same applies in turn to the total tax burden on labor income, $\tau^n+\phi+\phi^f$.[21] The value of the tax rate on bequests is set at 0.05 (our results are not sensitive to this).[22] The values of these tax instruments over 2001–2008 and over 2013–2017 are also presented in Table 2b.

5. POLICY REFORMS STUDIED

Our aim is to study the implications of a rich menu of hypothetical policy reforms. As said above, by reforms we mean permanent changes in the composition of taxes, spending, and public finance. In Section 6, where we depart from 2008, we will focus on expansionary fiscal policy changes, namely, tax cuts and spending rises; this is because, in the aftermath of the crisis, the policy task was how to stimulate the economy. In Section 7, where we depart from 2017, we will also add public debt consolidation to the list of reforms studied; this is because, once

TABLE 2b. Fiscal policy variables used in the solutions

Policy instruments	Description	2001–08	2013–17
τ^c	Consumption tax rate (effective)	0.193	0.202
τ^n	Labour income tax rate (effective)	0.130	0.130
τ^k	Personal capital income tax rate (effective)	0.285	0.335
ϕ	SSC paid by employees (effective)	0.080	0.100
ϕ^f	SSC contribution paid by employers (effective)	0.150	0.175
τ^f	Corporate income tax rate (effective)	0.210	0.17
τ^b	Bequest tax rate (set)	0.050	0.050
s_{tg^e}	Government spending on education as % of GDP	0.047	0.047
s_{tg^h}	Government spending on health as % of GDP	0.066	0.072
s_{tg^i}	Government spending on infrastructure as % of GDP	0.045	0.044
s_{tg^s}	Government spending on pensions as % of GDP	0.115	0.121
s_{tg^d}	Government spending on defense & public-order as % of GDP	0.030	0.029
s_{tg^c}	Government spending on the rest as % of GDP	0.165	0.170

the bust was over, there has been a lively debate on the need to bring public debt down [see e.g. Alesina et al. (2019)].

Before we list the policy reforms studied, it is worth clarifying the following. First, in all cases studied, we will depart from the associated *status quo* solution. This is defined as the steady-state solution of the equilibrium system in Subsection 3.4. In this numerical solution, variables do not change over time, and the parameter values and the exogenous fiscal policy instruments are set as in Tables 2a and 2b. Specifically, in Section 6, we will use fiscal data averages during 2001–2008 and in Section 7 data averages during 2013–2017. We report (results are available upon request) that the solutions obtained are meaningful and empirically relevant in the sense that most of the implied ratios are not different from their actual values in the data (e.g. consumption to GDP, public debt to GDP, private education spending to GDP, time allocated to work, the probability of an adult reaching the old age, etc.). Second, we will assume that any exogenous change in policy instruments is permanent so we will end up at a new reformed steady state. This is as in the literature on policy reforms mentioned in the Introductory section. Third, since it is well recognized that the macroeconomic implications of any exogenous change in fiscal policy are sensitive to the public financing instrument used (namely, which policy instrument adjusts residually in the government budget constraint so as to accommodate the exogenous change

TABLE 3. Policy reforms studied

Reforms	Description
R1	1 pp decrease in tax revenues from consumption taxes (via cuts in τ^c)
R2	1 pp decrease in tax revenues from labor income taxes (via cuts in τ^n)
R3	1 pp decrease in tax revenues from SSCs paid by employers (via cuts in ϕ^f)
R4	1 pp decrease in tax revenues from SSCs paid by employees (via cuts in ϕ)
R5	1 pp decrease in tax revenues from personal capital income taxes (via cuts in τ^k)
R6	1 pp decrease in tax revenues from corporate income taxes (via cuts in τ^f)
R7	1 pp increase in public spending on pensions (s^{g^s})
R8	1 pp increase in public spending on economic affairs (s^{g^i})
R9	1 pp increase in public spending on education (s^{g^e})
R10	1 pp increase in public spending on health (s^{g^h})
R11	1 pp increase in public spending on defense and public-order safety (s^{g^d})
R12	1 pp increase in overall public spending
R13	public debt consolidation

in fiscal policy), we will experiment with various cases: in particular, any exogenous changes in policy will be accommodated either by endogenous changes in the consumption tax rate, τ^c, or in the personal labor income tax rate, τ^n, or in the personal capital income tax rate, τ^k, or in the SSC paid by firms, τ^f, or in the end-of-period public debt, d_t^m, and this will happen both in the transition and in the new reformed steady state. Fourth, to make different policy experiments comparable, we have to compare changes in policy instruments that represent fiscal packages of the same size of GDP. In particular, all spending-tax changes below will worth 1% of GDP.[23] In the case of public spending, this is straightforward; for instance, a category of spending as share of GDP is increased by 1 pp (say, from 8% to 9% of GDP). In the case of tax rates, a tax rate will be cut so as the associated fall in tax revenues as share of GDP to be 1 pp again.[24] As we shall see and as should be expected, alternative reforms, although they bring in an equivalent change in the fiscal budget (here 1% of GDP), do not have the same effect in macro equilibrium.[25] Fifth, again in order to make the various policy experiments comparable, although we depart from the SQ solution where the social security system is self-financed via adjustments in ϕ, in the policy experiments below we will keep the value of ϕ as in the SQ solution and allow any exogenous changes in the social security system to be accommodated by the same variable as in the rest of the experiments (namely, via adjustments in τ^c, or τ^n, or τ^k, or d_t^m).[26] Finally, to understand the logic of our results, and following usual practice, we will consider one policy reform at a time.

The reforms studied are listed in Table 3. R1–R6 have to do with tax cuts. For instance, R1 assumes a cut in the consumption tax rate, τ^c, so as to get an 1 pp permanent decrease in consumption tax revenues. The same applies to R2–R6. Reforms R7–R12 are about spending rises. For instance, R7 assumes an 1 pp permanent increase on public pensions as share of GDP, s^{g^s}.[27] The same applies to

TABLE 4a. Lifetime output (depart 2008)

Reforms	τ^c adjusts	τ^n adjusts	τ^k adjusts	τ^f adjusts	d_t^m adjusts
SQ	0.8424	0.8424	0.8424	0.8424	0.8424
R1	–	0.8347	0.8365	0.8362	0.8522
R2	0.8500	–	0.8442	0.8438	0.8596
R3	0.8489	0.8424	0.8440	0.8436	0.8570
R4	0.8500	0.8424	0.8442	0.8438	0.8596
R5	0.8498	0.8398	–	0.8419	0.8622
R6	0.8474	0.8412	0.8427	–	0.8551
R7	0.8307	0.8231	0.8246	0.8245	0.8401
R8	0.8489	0.8394	0.8416	0.8412	0.8611
R9	0.8550	0.8459	0.8478	0.8473	0.8671
R10	0.8522	0.8431	0.8451	0.8446	0.8642
R11	0.8424	0.8332	0.8353	0.8350	0.8544
R12	0.8460	0.8389	0.8390	0.8386	0.8574

R8–R12. Notice that R12 involves a horizontal rise in all public spending activities. As said above, we will run R1–R12 when the residually determined public financing instrument is either τ^c, or τ^n, or τ^k, or d_t^m. We will also report what would have happened if the policy variables had remained constant at their departing values for ever (this is the SQ solution and will serve as a natural benchmark in each experiment). Finally, R13 describes the case of public debt consolidation; this case requires spending cuts and/or tax rises in the short run so it makes more sense to study it in Section 7 where we depart from post-crisis data.

6. FISCAL POLICY REFORMS AFTER 2008

Tables 4a and 4b report results under all reforms (except R13) listed in Table 3 when we depart from the year 2008 which was the last year before the crisis. As said in Section 5, the adjusting public financing instruments are in turn either the consumption tax rate, τ^c, or the labor income tax rate, τ^n, or the personal capital income tax rate, τ^k, or the corporate (profit) tax rate, τ_t^f, or the end-of-period public debt, d_t^m, and this is assumed to happen in each time period. Tables 4a and 4b report, respectively, results for discounted lifetime output ($\sum_{t=0}^{\infty} \beta^t y_t \equiv Y_t$) and discounted lifetime utility ($\sum_{t=0}^{\infty} \beta^t u_t \equiv U_t$) for each public financing case, while Table 4b also reports the implied utility gains, or losses, for each generation separately (young, adult, and old) vis-a-vis the associated welfare produced by the SQ solution, computed in terms of consumption equivalence units as in, for example, Lucas (1990), where a positive sign means a benefit vis-a-vis the SQ while a negative sign means a loss. Recall that in this section we start with the case in which we depart from the 2008 solution, which was the beginning of the Great Recession.

https://doi.org/10.1017/S1365100520000036 Published online by Cambridge University Press

TABLE 4b. Lifetime utility and welfare gains/losses (depart 2008)

	τ^c adjusts				τ^n adjusts				τ^k adjusts			
Reforms	U_t	ξ^y	ξ^m	ξ^o	U_t	ξ^y	ξ^m	ξ^o	U_t	ξ^y	ξ^m	ξ^o
SQ	−21.9963	0.0000	−0.0000	−0.0000	−21.9963	0.0000	0.0000	0.0000	−21.9963	0.0000	0.0000	0.0000
R1	–	–	–	–	−22.0536	0.0055	−0.0208	−0.0050	−22.0615	−0.0107	0.0051	−0.0194
R2	−21.9435	−0.0054	0.0198	0.0049	–	–	–	–	−22.0068	−0.0159	0.0246	−0.0136
R3	−21.9508	−0.0046	0.0170	0.0042	−21.9963	0.0000	0.0000	0.0000	−22.0048	−0.0136	0.0211	−0.0116
R4	−21.9435	−0.0054	0.0198	0.0049	−21.9963	0.0000	0.0000	0.0000	−22.0068	−0.0159	0.0246	−0.0136
R5	−21.9191	0.0131	−0.0069	0.0245	−21.9940	0.0199	−0.0334	0.0178	–	–	–	–
R6	−21.9478	0.0058	−0.0003	0.0133	−21.9932	0.0102	−0.0167	0.0092	−21.9974	−0.0025	0.0039	−0.0021
R7	−22.0833	−0.0081	−0.0191	−0.0004	−22.1427	−0.0027	−0.0401	−0.0055	−22.1515	−0.0190	−0.0145	−0.0203
R8	−22.0010	−0.0057	0.0002	0.0058	−22.0705	0.0009	−0.0249	−0.0003	−22.0800	−0.0186	0.0064	−0.0177
R9	−21.9308	−0.0010	0.0109	0.0151	−21.9971	0.0053	−0.0135	0.0094	−22.0074	−0.0135	0.0172	−0.0084
R10	−22.0288	−0.0063	0.0030	−0.0040	−22.0947	−0.0000	−0.0210	−0.0097	−22.1051	−0.0186	0.0092	−0.0270
R11	−22.0664	−0.0088	−0.0088	−0.0056	−22.1342	−0.0023	−0.0332	−0.0115	−22.1440	−0.0214	−0.0028	−0.0286
R12	−22.0190	−0.0057	−0.0024	0.0026	−22.0569	0.0009	−0.0195	−0.0008	−22.0946	−0.0180	0.0035	−0.0200

TABLE 4b. (Continued) Lifetime utility and welfare gains/losses (depart 2008)

	τ^f adjusts				d_t^m adjusts			
Reforms	U_t	ξ^y	ξ^m	ξ^o	U_t	ξ^y	ξ^m	ξ^o
SQ	−21.9963	0.0000	0.0000	0.0000	−21.9964	−0.0000	0.0000	0.0000
R1	−22.0595	−0.0074	−0.0000	−0.0166	−21.9413	−0.0127	0.0380	−0.0085
R2	−22.0043	−0.0126	0.0196	−0.0109	−21.8920	−0.0178	0.0570	−0.0035
R3	−22.0030	−0.0110	0.0173	−0.0096	−21.9062	−0.0150	0.0483	−0.0028
R4	−22.0043	−0.0126	0.0196	−0.0109	−21.8920	−0.0178	0.0570	−0.0035
R5	−21.9950	0.0040	−0.0064	0.0034	−21.8485	−0.0029	0.0406	0.0140
R6	–	–	–	–	−21.9036	−0.0039	0.0291	0.0069
R7	−22.1493	−0.0156	−0.0195	−0.0175	−22.0302	−0.0217	0.0186	−0.0090
R8	−22.0773	−0.0146	0.0002	−0.0143	−21.9342	−0.0214	0.0470	−0.0046
R9	−22.0046	−0.0096	0.0111	−0.0049	−21.8638	−0.0161	0.0575	0.0047
R10	−22.1024	−0.0148	0.0032	−0.0236	−21.9628	−0.0214	0.0492	−0.0145
R11	−22.1413	−0.0175	−0.0088	−0.0253	−22.0011	−0.0245	0.0373	−0.0161
R12	−22.0920	−0.0142	−0.0024	−0.0167	−21.9554	−0.0208	0.0422	−0.0074

Notes: A positive value for the consumption equivalence, ξ, means a welfare gain vis-a-vis the SQ.

Table 4a reveals that, across all experiments, the best reform, in terms of discounted lifetime output, is R9 (an increase in the share of public spending on education, $s_t^{g^e}$) being followed by R10 (an increase in the share of public spending on health, $s_t^{g^h}$), and this holds irrespectively of which public financing instrument adjusts to close the government budget constraint. Notice, on the other hand, that the biggest increase in output is obtained when R9 is financed by a temporary rise in public debt. Next to R9 and R10, in most experiments, we have R2 (a cut in labor income taxes, τ^n) or equivalently R4 (a cut in SSCs paid by employees, ϕ),[28] R3 (a cut in SSCs paid by firms, ϕ^f) and R5 (a cut in personal income taxes, τ^k) which also score well in terms of output (although less than R9 and R10), again irrespectively of the residual public financing instrument. In other words, increases in productive public spending like on education and health (R9 and R10) and cuts in particularly distorting taxes (R2, R3, R4, and R5) outscore the SQ as well as other reforms, which means that, if they had been implemented, they could have helped the Eurozone in the aftermath of the 2008 crisis. At the other end, the worst outcome, in terms of discounted lifetime output, is produced by R7 (an increase in the share of public spending on pensions, $s_t^{g^s}$) which is inferior even to the SQ across all experiments. The rest of the policy regimes lie in between. Finally, notice that across almost all reforms, the worst outcome is obtained when an expansionary fiscal change is financed by τ^n; namely, it is not a good idea to finance rises in spending, and/or cuts in other taxes, by an increase in labor taxes because the latter are particularly distorting. Impulse response functions, IRFs, presented below will provide a better understanding of these results.

Table 4b reports results for social discounted lifetime utility, as well as the resulting welfare gains (positive numbers) or losses (negative numbers) for each generation separately relative to the SQ solution in the year 2008. Before we discuss results, it is worth recalling that the arguments in the utility function include consumption, leisure, bequests, and several types of public spending (see equation (1) above), which can be affected in various directions by each policy reform; hence, results for welfare are expected be less clear-cut than results for output. This is the case indeed. Welfare results vary depending on the residually determined public financing instrument, although, in most cases, R5 (a cut in personal capital income taxes, τ^k) scores better than the other regimes. Mixed results are also derived when we look at gains/losses for each generation separately. Nevertheless, some messages are clear. Specifically, as in terms output in Table 4a, R7 (an increase in the share of public spending on pensions, $s_t^{g^s}$) delivers the worst social welfare in all cases. Notice also that, under R7, ξ^o is negative in all cases in Table 4b; in other words, an increase in $s_t^{g^s}$ proves to be counterproductive even to the old who are supposed to be the main beneficiaries of such policy.

The corresponding IRFs for R2 = R4, R3, R5, R7, R9, and R10 are shown in Figure 1.[29] Inspection reveals that the output benefits from higher spending on education and health (R9 and R10) and in turn from lower distorting taxes (R2,

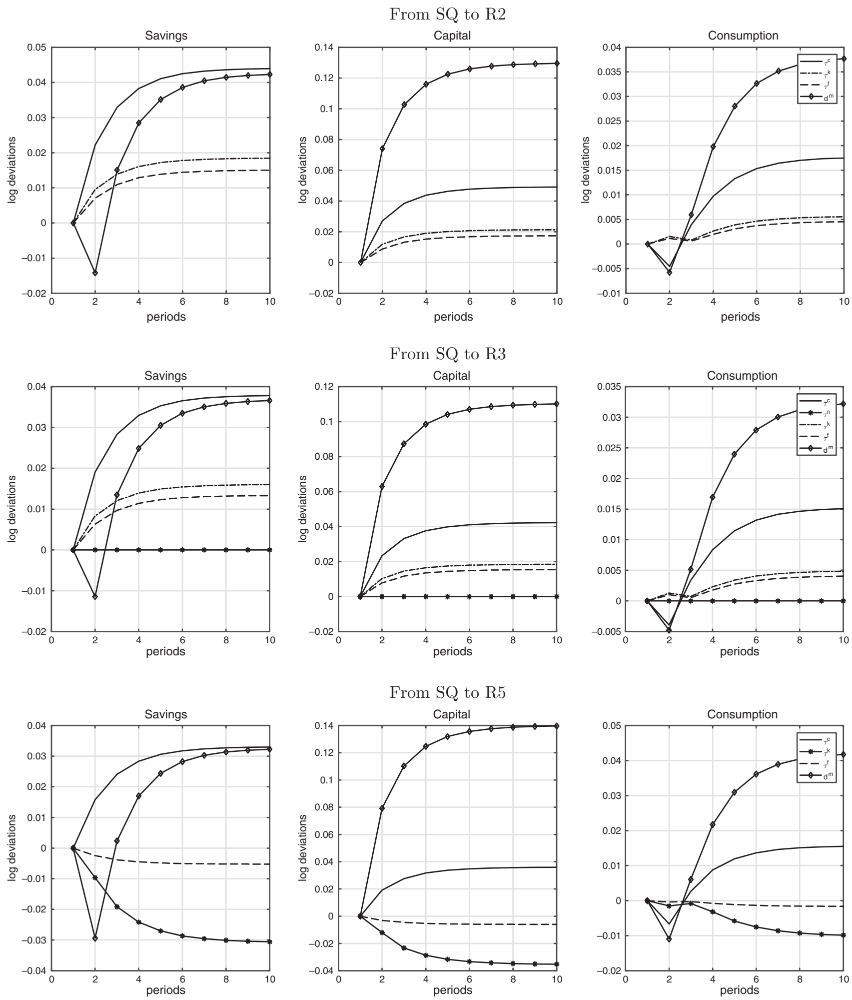

FIGURE 1. Transition from SQ to reformed economies (depart 2008)

R3, R4, and R5) arise mainly because all these types of policy reforms encourage private agents to save more and this helps capital accumulation and consumption in equilibrium. The same IRFs also show that the choice of the public financing instrument matters to macroeconomic variables. For instance, the beneficial effect of these reforms upon savings, capital, and consumption is much stronger when the increase in productive public spending and/or a cut in distorting taxes is accommodated by a temporary rise in public debt or an increase in consumption taxes rather than by an increase in a distorting tax and especially labor taxes. At the other end, the same figures explain why R7 scores the worst, both in terms of output and social welfare. Namely, a rise in public spending on pensions hurts

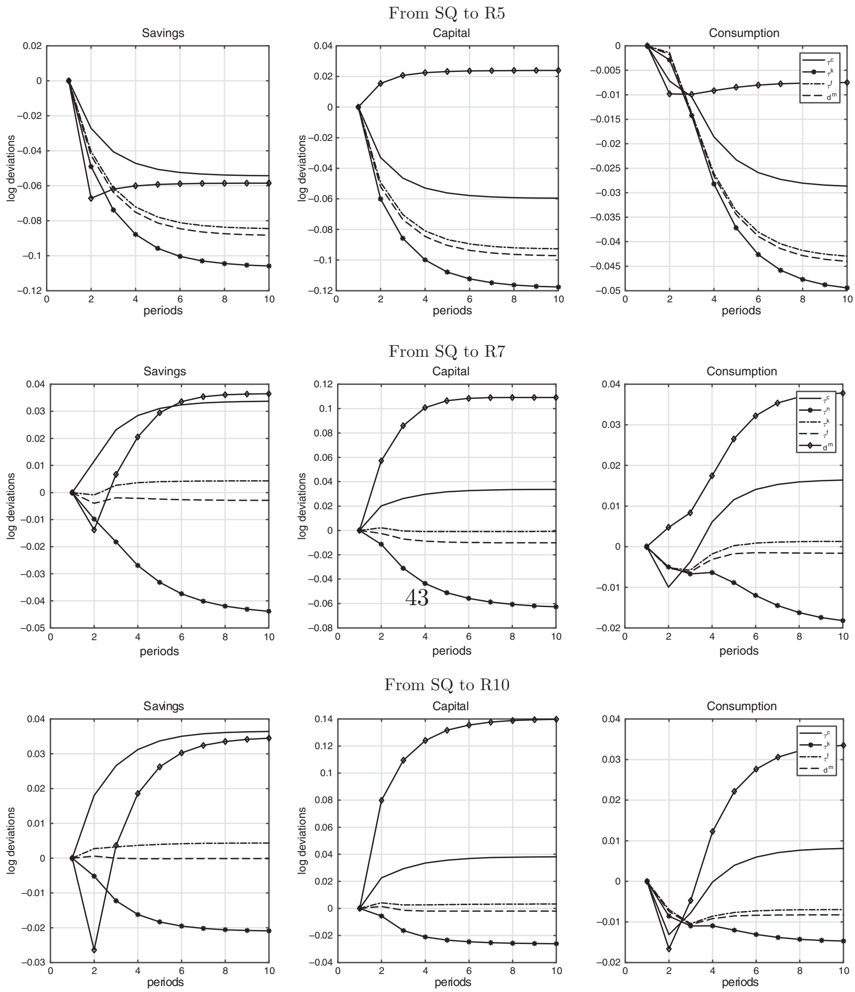

FIGURE 1. Continued

the incentive to save (the adverse effect on savings is especially strong when the rise in spending on pensions is financed by higher taxes on labor income, τ^n).[30] This also explains the negative values of ξ^o: the indirect harm from lower private savings and lower GDP more than outweighs any direct benefits from the policy attempt to allocate more social resources to pensions. Finally, we report that R9 exerts, as expected, a strong positive effect on human capital which stimulates output (the IRFs for human capital are available upon request). We also report that R9 does not score so well as perhaps would be expected in terms of welfare simply because, with a richer human capital, the incentive to leave a financial bequest weakens and, since bequests are a direct argument in the utility function,

https://doi.org/10.1017/S1365100520000036 Published online by Cambridge University Press

TABLE 5a. Lifetime output (depart 2017)

Reforms	τ^c adjusts	τ^n adjusts	τ^k adjusts	τ^f adjusts	d_t^m adjusts
SQ	0.7470	0.7470	0.7470	0.7470	0.7470
R1	–	0.7382	0.7420	0.7413	0.7539
R2	0.7547	–	0.7505	0.7497	0.7611
R3	0.7531	0.7470	0.7498	0.7492	0.7582
R4	0.7547	0.7470	0.7505	0.7497	0.7611
R5	0.7540	0.7415	–	0.7460	0.7634
R6	0.7515	0.7446	0.7476	–	0.7569
R7	0.7368	0.7275	0.7312	0.7305	0.7439
R8	0.7529	0.7419	0.7466	0.7457	0.7616
R9	0.7580	0.7476	0.7519	0.7509	0.7662
R10	0.7554	0.7452	0.7495	0.7486	0.7635
R11	0.7470	0.7365	0.7410	0.7401	0.7553
R12	0.7501	0.7398	0.7378	0.7433	0.7589

this exerts a direct negative effect on welfare (the IRFs for bequests that illustrate this effect are available upon request).

7. FISCAL POLICY REFORMS AFTER 2017

In this section, we depart from the year 2017. As said, this will enable us to study what can happen from now on depending on the policy mix adopted. Results are given in Subsection 7.1. Then, in Subsection 7.2, we will add public debt consolidation to the list of reforms, while, in Subsection 7.3, we will also allow for demographic problems. Note that all experiments in this section depart from the 2017 solution.

7.1. Results

Results are reported in Tables 5a and 5b which are exactly like Tables 4a and 4b except for the new departing point. The main results remain unchanged. For instance, in terms of discounted lifetime output, R9 is the best and R7 is the worst (in all cases). R7 also delivers the lowest discounted lifetime utility (almost in most cases) and hurts the old people (in all cases). On the other hand, there are also some new messages. For example, looking for second-best choices when the criterion is discounted lifetime output, the comparison between an increase in spending on health (R10) and tax cuts (R2, R3, R4, and R5) is now not so clear. Recall that R10 was better than R2, R3, R4, and R5 in Table 4a. This is not always the case now. In other words, in the new era of high public debts, tax cuts become more attractive. This is further studied in the next subsection with debt consolidation. The IRFs for R2 = R4, R3, R5, R7, R9, and R10 in Figure 2 are qualitatively as those in Figure 1.

TABLE 5b. Lifetime utility and welfare gains/losses (depart 2017)

	τ^c adjusts				τ^n adjusts				τ^k adjusts			
Reforms	U_t	ξ^y	ξ^m	ξ^o	U_t	ξ^y	ξ^m	ξ^o	U_t	ξ^y	ξ^m	ξ^o
SQ	−22.9583	0.0000	−0.0000	0.0000	−22.9583	−0.0000	−0.0000	−0.0000	−22.9583	−0.0000	−0.0000	−0.0000
R1	–	–	–	–	−23.0426	0.0059	−0.0292	−0.0058	−23.0160	−0.0094	0.0047	−0.0177
R2	−22.8885	−0.0053	0.0247	0.0054	–	–	–	–	−22.9374	−0.0135	0.0285	−0.0089
R3	−22.9022	−0.0042	0.0198	0.0043	−22.9583	−0.0000	−0.0000	−0.0000	−22.9408	−0.0107	0.0228	−0.0070
R4	−22.8885	−0.0053	0.0247	0.0054	−22.9583	−0.0000	−0.0000	−0.0000	−22.9374	−0.0135	0.0285	−0.0089
R5	−22.8820	0.0127	−0.0073	0.0252	−23.0042	0.0207	−0.0487	0.0169	–	–	–	–
R6	−22.9108	0.0051	0.0007	0.0125	−22.9758	0.0096	−0.0219	0.0080	−22.9543	−0.0021	0.0046	−0.0014
R7	−23.0487	−0.0076	−0.0204	−0.0007	−23.1427	−0.0013	−0.0523	−0.0069	−23.1155	−0.0179	−0.0156	−0.0209
R8	−22.9604	−0.0054	0.0005	0.0062	−23.0656	0.0019	−0.0357	−0.0012	−23.0319	−0.0170	0.0064	−0.0158
R9	−22.8958	−0.0013	0.0108	0.0144	−22.9940	0.0056	−0.0237	0.0077	−22.9643	−0.0123	0.0167	−0.0073
R10	−22.9926	−0.0068	0.0034	−0.0047	−23.0886	−0.0001	−0.0298	−0.0113	−23.0590	−0.0175	0.0091	−0.0251
R11	−23.0263	−0.0085	−0.0085	−0.0055	−23.1272	−0.0014	−0.0431	−0.0124	−23.0957	−0.0197	−0.0029	−0.0266
R12	−22.9818	−0.0057	−0.0025	0.0023	−23.0807	0.0011	−0.0366	−0.0044	−23.1948	−0.0368	−0.0003	−0.0460

Table 5b. (Continued) Lifetime utility and welfare gains/losses (depart 2017)

	τ^f adjusts				d_t^m adjusts			
Reforms	U_t	ξ^y	ξ^m	ξ^o	U_t	ξ^y	ξ^m	ξ^o
SQ	−22.9583	0.0000	0.0000	0.0000	−22.9583	0.0000	0.0000	0.0000
R1	−23.0210	−0.0065	−0.0014	−0.0159	−22.8763	−0.0001	0.0309	−0.0049
R2	−22.9417	−0.0108	0.0232	−0.0076	−22.8169	−0.0054	0.0521	0.0016
R3	−22.9442	−0.0088	0.0189	−0.0061	−22.8449	−0.0043	0.0413	0.0014
R4	−22.9417	−0.0108	0.0232	−0.0076	−22.8169	−0.0054	0.0521	0.0016
R5	−22.9657	0.0038	−0.0084	0.0025	−22.7690	0.0130	0.0355	0.0174
R6	–	–	–	–	−22.8474	0.0051	0.0247	0.0084
R7	−23.1204	−0.0148	−0.0222	−0.0188	−22.9602	−0.0079	0.0126	−0.0061
R8	−23.0379	−0.0134	−0.0012	−0.0136	−22.8590	−0.0055	0.0393	−0.0004
R9	−22.9696	−0.0089	0.0094	−0.0049	−22.8003	−0.0014	0.0480	0.0078
R10	−23.0644	−0.0141	0.0020	−0.0230	−22.8987	−0.0068	0.0395	−0.0108
R11	−23.1014	−0.0162	−0.0102	−0.0244	−22.9280	−0.0086	0.0286	−0.0115
R12	−23.0558	−0.0133	−0.0041	−0.0166	−22.8858	−0.0042	0.0313	−0.0025

Notes: A positive value for the consumption equivalence, ξ, means a welfare gain vis-a-vis the SQ.

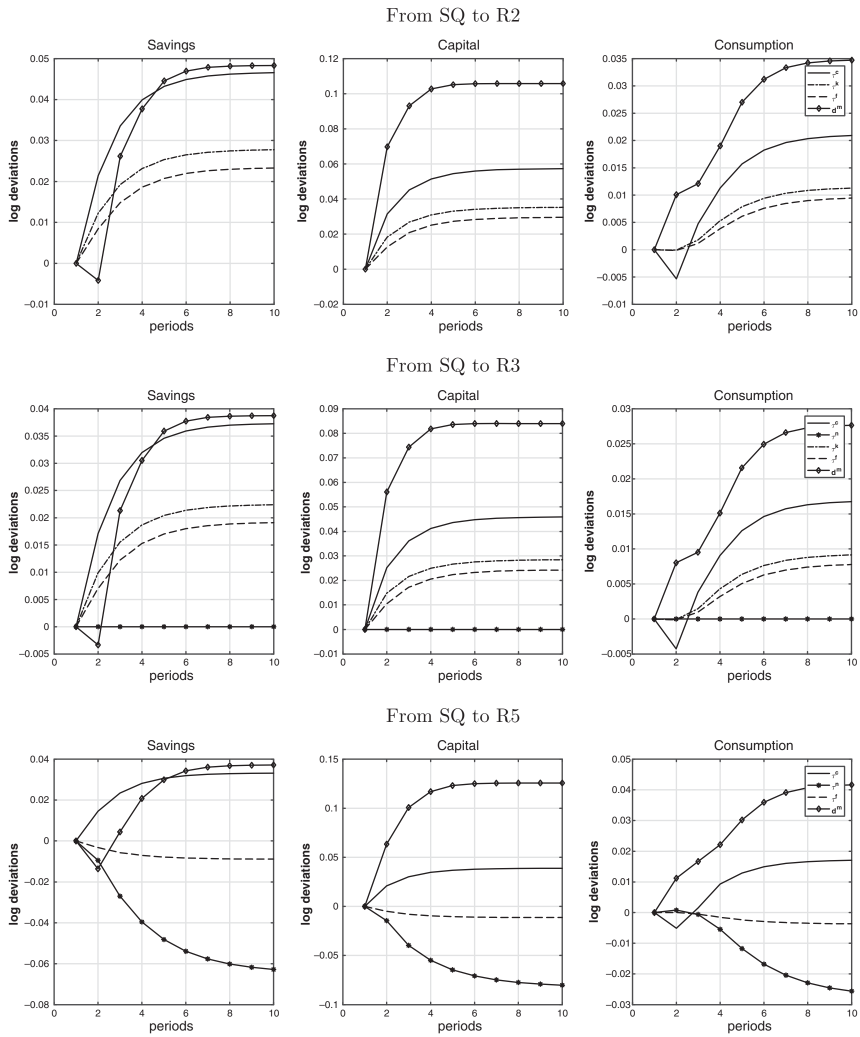

FIGURE 2. Transition from SQ to reformed economies (depart 2017)

7.2. Adding Public Debt Consolidation

In this subsection, we allow for an extra reform, denoted as R13, which is the case of public debt consolidation. This regime is motivated by the substantial increase in public debt caused by automatic stabilizers, as well as the discretionary measures taken by most governments, during the Great Recession. In the Eurozone, for example, the public debt-to-GDP ratio was around 70% in 2008, while it is around 87% today. Are fiscal austerity and public debt consolidation expansionary or contractionary? In addition, there has been a debate over Germany's choice

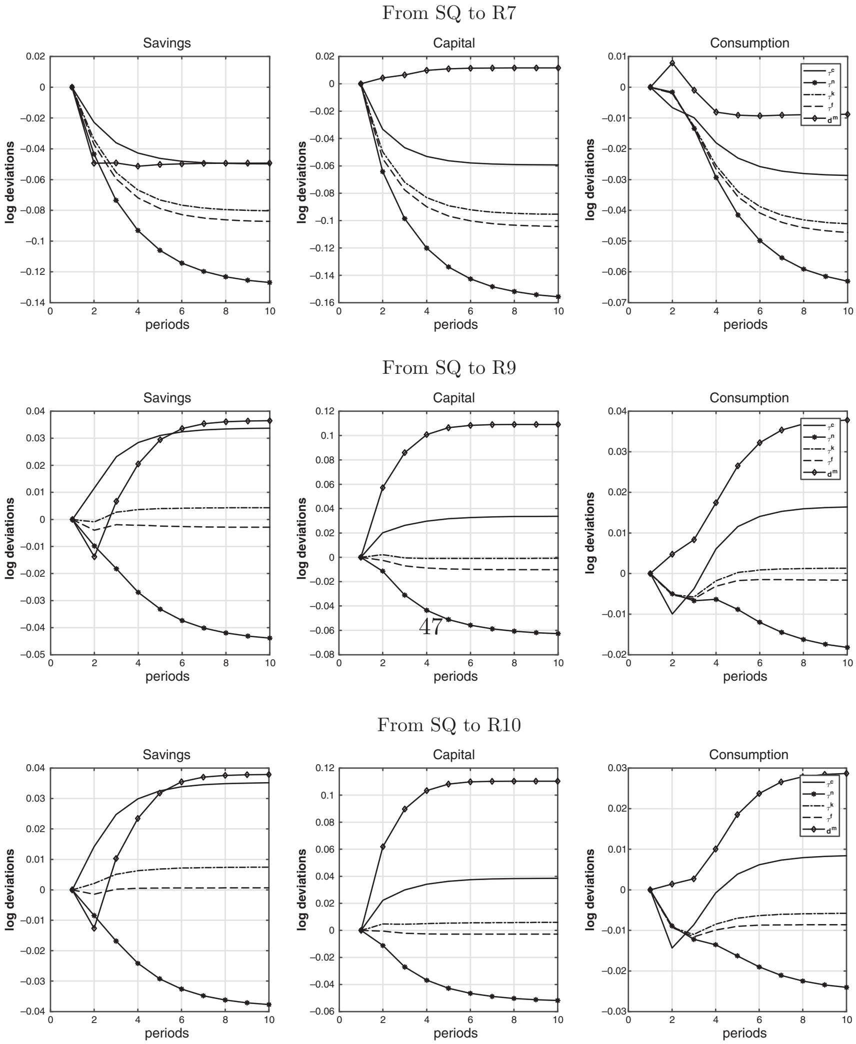

FIGURE 2. Continued

to follow a relatively conservative fiscal policy even if its public debt-to-GDP ratio is around 60% these days; should its government spend more?

There is a big and still growing literature on public debt consolidation.[31] Most of this literature models public debt consolidation by assuming feedback policy rules, according to which fiscal instruments react to the gap between the public debt to GDP ratio and a policy target which is usually set at 60% as in the Maastricht Treaty criteria. A general result from this literature is that the intertemporal effects of public debt consolidation depend crucially on the policy mix used and, specifically, on which fiscal instruments bear the fiscal cost of bringing the

TABLE 6a. Lifetime output (R13, depart 2017)

Reforms	τ^c adjusts	τ^n adjusts	τ^k adjusts	τ^f adjusts	d_t^m adjusts
R13	0.7624	0.7811	0.7737	0.7761	–

public debt down in the short term and on which fiscal instruments (are expected to) take advantage of the fiscal space created in the medium and long term once the debt burden has been brought down. A full investigation of all possible mixes is beyond the scope of this paper. Here, we will just assume that only one instrument is used at a time, meaning that the same instrument is used both to bring public debt down along the transition and to take advantage of the fiscal space in the new reformed steady state. The policy instruments used will be the consumption tax rate, τ_t^c, the labor income tax rate, τ_t^n, the capital income tax rate, τ_t^k, and the profit tax rate, τ_t^f (these are the instruments that have so far functioned as residually determined public financing variables in our experiments).

Modeling and calibration details are provided in Appendix C. Here, we just report the main results from R13 in Tables 6a and 6b and Figure 3. Inspection of the results in Tables 5a and 5b and 6a and 6b reveals that R13 is superior to all other regimes both in terms of lifetime output and lifetime utility (we report that we have experimented with several cases and this is a robust result). In terms of lifetime output, the superiority of R13 is stronger when τ_t^n, τ_t^k or τ_t^f are the residual public financing instruments. That is, the anticipation of cuts in relatively distorting taxes, once the public debt burden has been reduced thanks to consolidation, is especially beneficial to real activity over time. Observe also that R13 can be good for all agents; see, for example, the positive values of ξ^y, ξ^m and ξ^o when τ_t^k or τ_t^f are the residual public financing instruments. However, a word of caution is necessary here: our OLG model (where one period corresponds to around 25 years) is, by construction, more suitable to the study of the medium and long term, in the sense that any short-term costs of public debt consolidation can be underestimated. Finally, inspection of the IRFs in Figure 2 and the IRF for R13 in Figure 3 reveals that public debt consolidation generates an impressive rise in capital (crowd in effect) and consumption relative to the regimes in Figure 2. Overall, these results can provide a rationale for Germany's current conservative fiscal policy to the extent that one is willing to focus on medium- and long-run horizons.

7.3. Allowing for Declining and Ageing Population

One of the demographic concerns in the EU, and especially in the Eurozone, is underbirth and ageing. To capture this, we enrich the experiments of the previous subsection by assuming a negative value of population growth, n, which means underbirth, and a larger value for Ξ, which means that the probability of reaching the old age increases other things equal.[32] In particular, we now set n and Ξ so as

TABLE 6b. Lifetime utility and welfare gains/losses (R13, depart 2017)

	τ^c adjusts				τ^n adjusts				τ^k adjusts			
Reforms	U_t	ξ^y	ξ^m	ξ^o	U_t	ξ^y	ξ^m	ξ^o	U_t	ξ^y	ξ^m	ξ^o
R13	−22.7821	−0.0006	0.0675	−0.0098	−22.6643	−0.0070	0.1007	0.0096	−22.6543	0.0202	0.0569	0.0298

TABLE 6b. (Continued) Lifetime Utility and welfare gains/losses (R13, depart 2017)

	τ^f adjusts				d_t^m adjusts			
Reforms	U_t	ξ^y	ξ^m	ξ^o	U_t	ξ^y	ξ^m	ξ^o
R13	−22.6485	0.0139	0.0696	0.0252	–	–	–	–

Notes: A positive value for the consumption equivalence, ξ, means a welfare gain vis-a-vis the SQ.

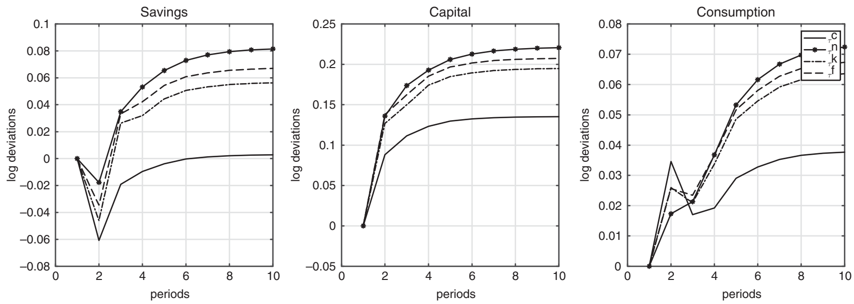

FIGURE 3. Transition from SQ to reformed economies (R13, depart 2017)

the fraction of old households increases by 5%–7% over time.[33] The new results are in Tables 7a and 7b which should be compared to those in Tables 5a and 5b and 6a and 6b. As can be seen, the qualitative results remain as above. For example, R13 scores the best both in terms of aggregate output and aggregate welfare (especially, when τ_t^n, τ_t^k , or τ_t^f are the residual public financing instruments), being followed by R9, while, at the other end, R7 gives again the worst outcome both in terms of output and welfare and also hurts the old.[34]

8. FURTHER SENSITIVITY ANALYSIS

In this section, we check the robustness of the above results to changes in parameter values as well as to modifications of the model. Regarding parameter values, we will focus on parameters whose values are relatively unknown (this is in Subsections 8.1 and 8.2). We repeat however that we have also experimented with changes in all other parameter values listed in Table 2a, whose values are more conventional, and the results do not change. With regard to changes in the model, we will allow public spending on defense and public-order safety to play an extra role (this is in Subsection 8.3) and an entirely self-financed PAYG public pension system (this is Subsection 8.4), while other model modifications are discussed briefly at the end (this is in Subsection 8.5). The departure point in this section is the *status quo* in 2017 which means that the baseline results are those of the previous Section 7 (however, our results are not affected when we depart from

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TABLE 7a. Lifetime output (depart 2017 plus ageing)

Reforms	τ^c adjusts	τ^n adjusts	τ^k adjusts	τ^f adjusts	d_t^m adjusts
SQ	0.8437	0.8327	0.8406	0.8394	0.8495
R1	0.0000	0.8226	0.8343	0.8335	0.8550
R2	0.8528	–	0.8439	0.8428	0.8637
R3	0.8509	0.8327	0.8433	0.8423	0.8608
R4	0.8528	0.8327	0.8439	0.8428	0.8637
R5	0.8534	0.8265	–	0.8401	0.8674
R6	0.8487	0.8291	0.8402	–	0.8591
R7	0.8296	0.8079	0.8190	0.8188	0.8407
R8	0.8513	0.8268	0.8395	0.8389	0.8642
R9	0.8575	0.8336	0.8460	0.8451	0.8701
R10	0.8540	0.8304	0.8428	0.8419	0.8665
R11	0.8437	0.8200	0.8325	0.8319	0.8563
R12	0.8473	0.8238	0.8360	0.8354	0.8597
R13	0.8570	0.8689	0.8692	0.8669	–

Notes: (i) The values of n and Ξ have been chosen so as the share of the old increases gradually by around 5%–7%. (ii) In this scenario, the SQ solution for each residually determined policy instrument is different since we are imposing from the beginning a demographic change.

the *status quo* in 2008 in which case the baseline results are those of Section 6). To save on space, in what follows, we will just report the main findings without presenting numerical solutions or IRFs (they are available upon request).

8.1. The Role of Private Spending on Education

In the solutions so far, the value of the parameter $0 \leq \gamma \leq 1$, which is the weight given to private spending vis-a-vis public spending in the production function for new human capital (see equation (6)), has been set at 0.25. As said, this parameter value resulted in a solution for private spending on education close to the Eurozone data (0.5% of GDP). Our results remain qualitatively unchanged for values of γ in the range between 0 and around 0.4. Above 0.4, as expected, R9 and R10 (namely, higher public spending on education and health) lose some of their appeal. It is important to point out, however, that a value of γ above 0.4 results in solutions for the output share of private education spending outside the range of historical values (for instance, when we set $\gamma = 0.5$, this share rises to 2.5% of GDP).

We also report that our results do not change when the related elasticity parameter, ν, rises, so that the elasticity of substitution between private and public education spending, $1/(1-\nu)$, also rises. In particular, our results do not change when ν rises from 0.5 (which was its value in the baseline parameterization) to around 0.8.

Table 7b. Lifetime utility and welfare gains/losses (depart 2017 plus ageing)

	τ^c adjusts				τ^n adjusts				τ^k adjusts			
Reforms	U_t	ξ^y	ξ^m	ξ^o	U_t	ξ^y	ξ^m	ξ^o	U_t	ξ^y	ξ^m	ξ^o
SQ	−22.4332	0.0000	0.0000	0.0000	−22.5296	0.0000	0.0000	0.0000	−22.4683	−0.0000	−0.0000	0.0000
R1	–	–	–	–	−22.6179	0.0054	−0.0281	−0.0075	−22.5230	−0.0068	0.0049	−0.0191
R2	−22.3619	−0.0052	0.0238	0.0066	–	–	–	–	−22.4471	−0.0117	0.0280	−0.0102
R3	−22.3760	−0.0041	0.0190	0.0053	−22.5296	0.0000	0.0000	0.0000	−22.4506	−0.0093	0.0224	−0.0080
R4	−22.3619	−0.0052	0.0238	0.0066	−22.5296	0.0000	0.0000	0.0000	−22.4471	−0.0117	0.0280	−0.0102
R5	−22.3586	0.0092	−0.0087	0.0294	−22.5947	0.0171	−0.0521	0.0177	–	–	–	–
R6	−22.3859	0.0035	−0.0000	0.0147	−22.5551	0.0080	−0.0234	0.0085	−22.4640	−0.0018	0.0045	−0.0015
R7	−22.5177	−0.0055	−0.0209	−0.0003	−22.7174	0.0003	−0.0529	−0.0087	−22.6188	−0.0131	−0.0160	−0.0229
R8	−22.4380	−0.0065	−0.0004	0.0069	−22.6506	0.0006	−0.0372	−0.0030	−22.5442	−0.0152	0.0063	−0.0184
R9	−22.3670	−0.0022	0.0099	0.0173	−22.5714	0.0043	−0.0250	0.0083	−22.4701	−0.0105	0.0167	−0.0077
R10	−22.4821	−0.0080	0.0021	−0.0062	−22.6841	−0.0015	−0.0316	−0.0151	−22.5839	−0.0161	0.0085	−0.0299
R11	−22.5108	−0.0092	−0.0093	−0.0074	−22.7180	−0.0024	−0.0444	−0.0167	−22.6151	−0.0176	−0.0030	−0.0317
R12	−22.4598	−0.0060	−0.0034	0.0026	−22.6651	0.0005	−0.0379	−0.0066	−22.5632	−0.0143	0.0028	−0.0216
R13	−22.2358	0.0176	0.0609	−0.0009	−22.1531	0.0102	0.0929	0.0058	−22.1382	0.0288	0.0526	0.0342

Notes: (i) The values of n and Ξ have been chosen so as the share of the old increases gradually by around 5%–7%. (ii) In scenario, the SQ solution for each residually determined policy instrument is different since we are imposing from the beginning a demographic shock

TABLE 7b. (Continued) Lifetime utility and welfare gains/losses (depart 2017 plus ageing)

	τ^f adjusts				d_t^m adjusts			
Reforms	U_t	ξ^y	ξ^m	ξ^o	U_t	ξ^y	ξ^m	ξ^o
SQ	−22.4810	0.0000	0.0000	0.0000	−22.3565	0.0000	0.0000	0.0000
R1	−22.5412	−0.0043	−0.0009	−0.0174	−22.2739	0.0042	0.0267	−0.0045
R2	−22.4637	−0.0091	0.0227	−0.0087	−22.2113	−0.0011	0.0481	0.0024
R3	−22.4655	−0.0076	0.0189	−0.0068	−22.2402	−0.0009	0.0382	0.0020
R4	−22.4637	−0.0091	0.0227	−0.0087	−22.2113	−0.0011	0.0481	0.0024
R5	−22.4895	0.0032	−0.0084	0.0028	−22.1566	0.0159	0.0317	0.0220
R6	–	–	–	–	−22.2401	0.0072	0.0223	0.0106
R7	−22.6373	−0.0104	−0.0224	−0.0207	−22.3497	−0.0011	0.0081	−0.0053
R8	−22.5637	−0.0120	−0.0013	−0.0160	−22.2527	−0.0008	0.0350	0.0005
R9	−22.4888	−0.0075	0.0094	−0.0052	−22.1881	0.0030	0.0441	0.0107
R10	−22.6026	−0.0131	0.0014	−0.0276	−22.3044	−0.0027	0.0352	−0.0124
R11	−22.6342	−0.0145	−0.0103	−0.0294	−22.3293	−0.0038	0.0245	−0.0135
R12	−22.5820	−0.0113	−0.0043	−0.0193	−22.2816	−0.0008	0.0298	−0.0035
R13	−22.1442	0.0246	0.0594	0.0292	–	–	–	–

Notes: A positive value for the consumption equivalence, ξ, means a welfare gain vis-a-vis the SQ.

8.2. The Role of Public Spending on Health

We now study robustness to the values of the parameter λ in equation (6). Recall that λ measures the extent to which public spending on health contributes to the creation of new human capital alongside with public spending on education (as argued above, not only education, skills, and knowledge but also health and longevity can be crucial to human capital). Also recall that the results so far have been with $\lambda = 0.5$, which can be thought of as a neutral value. As expected, as λ rises, R10 becomes more productive especially in terms of lifetime output. Actually, when we set λ around 0.9, then R9 and R10 become very similar. Namely, an increase in public spending on health (R10) becomes as good as an increase in public spending on education (R9) to the extent that the former also augments human capital.

8.3. An Extra Role of Public Spending on Defense and Public-Order Safety

In the analysis so far, we have treated public spending on defense and public-order safety as a utility-enhancing policy activity only. One could claim, however, that this type of policy also provides productivity-enhancing services. For instance, it is widely recognized that public spending on defense and public-order safety (police, courts, prisons, national security, etc.) is also necessary for the protection of property rights. We therefore augment the model to allow for weak property rights and thereby give a richer, and potentially more useful, role to public spending on defense and public-order safety. In terms of modeling, we assume that each firm can appropriate only a fraction $0 < p \leq 1$ of its output produced, y_t^f, because the rest, $(1 - p)\, y_t^f$, can be taken away by other agents (say, the adult households), while the degree of protection of property rights, p, depends on public expenditure on defense and public-order safety as share of output, $s_t^{g^d} \equiv \frac{G_t^d}{N_t^f y_t^f}$.[35] This richer version of the model is presented in Appendix C. Here, we just report the main results. As expected, R11 (namely, an increase in public spending on defense and public-order safety) ranks much higher now, especially in terms of lifetime output, although in most experiments it cannot outperform R9. In other words, R13 and R9 remain at the top, but, on the other hand, the new results highlight the vital role of public policy in the protection of property rights in countries with poor institutional quality. It is worth reporting here that in our experiments, the solution for the degree of property rights, p, is around 0.85, which is close to the international property rights index for the EU (see e.g. the World Bank database).

8.4. An Entirely Self-Financed PAYG Public Pension System

So far, in the transition to a new reformed steady state, we have studied a PAYG system in which only a part of total public spending on pensions was financed out of the social security taxes, ϕ_t and ϕ_t^f, while the rest (i.e. any difference between spending and receipts collected from social security taxes) was financed out of the general government budget. This has made all regime changes comparable as discussed in Section 5 above and perhaps is also closer to reality. In this subsection, we study the case in which the PAYG system is entirely self-financed, meaning that spending on pensions is financed by endogenous adjustments in ϕ_t in each time period (s^{g^s} and ϕ_t^f are again set as in the data). In other words, now, as explained in Subsection 3.3.1, there is a separate budget constraint for the PAYG system (19), which is satisfied by adjustments of ϕ_t in each period, while the government budget constraint (20) is satisfied by adjustments of the end-of-period public debt. We label this new regime as R7(s). As perhaps should be expected, R7(s), namely, an increase in spending on public pensions, which is fully financed by rises in social security contributions, is clearly inferior (both in terms of lifetime output and lifetime utility) to both the SQ and R7. This happens because R7(s) implies higher social security contributions/taxes and, as we have seen above, the latter are particularly distorting. Thus, the detrimental effect of a rise in spending on public pensions becomes even stronger now.

8.5. Other Changes in the Model

We finally briefly report some other robustness results (details are available upon request). First, as already said above, we have experimented with the case in which young households can also borrow (say, from adult or old households) to finance their private spending on education (see the budget constraints (2)–(4) above). The main results do not change. Second, we have experimented with alternative public pension systems, like a fully funded system, in which the government collects social security taxes from adults at time $t+1$ (as above), invests them in physical capital with a return $(1-\delta^k+r_{t+1})$ and then distributes the resulting amount to the same individuals when they reach the old age; this is the best possible case in the sense that all related funds are invested in capital [see e.g. Acemoglu (2009, chapter 9.5)]. A sketch of this model is in Appendix D. We report that again the main results do not change, although one has to change the baseline parameterization of the model in order to get solutions under both public pension systems.

9. CONCLUDING REMARKS, CAVEATS, AND POSSIBLE EXTENSIONS

In this paper, we built a general equilibrium OLG model that included the most important categories of spending and taxes in the data. We then carried out a number of (actual or hypothetical) policy experiments to see what happens when spending, tax, and public finance instruments change vis-a-vis their data average values.

Since the main results have already been listed in the introductory section, here we close with caveats and extensions. Regarding social protection spending, it is worth keeping in mind that here we assumed that capital markets are perfect (for instance, there are no binding borrowing constraints) so that agents can smooth consumption and insure themselves via private saving. It would be interesting though to see what happens when capital markets are not perfect in which case social security is not a perfect substitute for private saving and borrowing [see e.g. Krueger and Perri (2011) and the reviews of inequality and policy by Heathcote et al. (2009) and Quadrini and Ríos-Rull (2014)]. Also, recall that, in the analysis above, we assumed that differences in age are the only source of heterogeneity across individuals. It would be interesting to add other sources. For instance, we could assume that households are also heterogeneous at birth, namely, there are rich-born households and poor-born households so that there are differences among households within any given cohort. In this case, public education spending may have an even stronger role to play [see e.g. Cunha and Heckman (2009) for this literature]. Finally, we could search for optimal policies [see e.g. Park and Philippopoulos (2002), Economides et al. (2011), and Angelopoulos et al. (2019)]. We leave these extensions for future work.

NOTES

1. See e.g. European Commission (2017, 2018a) and ECB (2017).

2. There are several ways to classify government expenditures and taxes. Here we divide expenditures into their functional (COFOG) categories (see Table 1a), while we classify tax revenues according to the type of tax (see Table 1b). We focus on these classifications or breakdowns because they have become a prominent issue in the European policy debate, especially since the 2008 crisis. Theoretical studies, by contrast, usually break down expenditures according to their economic characteristics (government consumption, investment, and transfers) and tax revenues according to their economic function meaning the factor of production (taxes on labor, capital, and consumption).

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 categories of public spending and tax revenues in a unified general equilibrium framework. For instance, Blankenau and Simpson (2004), Blankenau (2005), Arcalean and Schiopu (2010), Abington and Blankenau (2013) and Viaene and Zilcha (2013), among many others, have focused on public education spending. Cooley and Soares (1999), Krueger and Kubler (2006), Conesa and Garriga (2008), Bassetto (2008), Auerbach and Lee (2011), Kaganovich and Zilcha (2012), Bruce and Turnovsky (2013), etc., have focused on social security. Bhattacharya and Qiao (2007), among others, have focused on health spending. OLG papers with a richer mix of spending policy instruments include Bouzahzah et al. (2002), Soares (2006), and de la Croix and Michel (2002), who have studied both public education and social security, and Dioikitopoulos (2014), who has studied both public health and education. Most of the above papers use a simple tax structure. Glomm et al. (2009) develop an OLG model with a rich spending and tax structure, but they focus on pension policies in the private and public sectors. Glomm et al. (2018) also incorporate a rich variety of government activities but they focus on debt consolidation and the role of the risk premium in an OLG model calibrated to the Greek economy. Finally, econometric studies on the growth effects of different types of public spending include Bleaney et al. (1999, 2001), Shelton (2007), Gemmell et al. (2012, 2014), and Acosta-Ormaechea and Morozumi (2013), while a review of the earlier empirical literature can be found in European Commission (2008, part III).

4. The use of Eurozone data means that our policy results can apply to a country in an "average" fiscal and budgetary situation. Debt crisis-afflicted countries (such as Greece, Cyprus, Portugal, or Italy) may require different policy measures.

5. That is, here we do not study temporary changes in fiscal policies aiming at short-term stabilization which are typically measured by impact multipliers. Instead, we are closer to papers on fiscal

reforms, like Lucas (1990), Cooley (1992), Mendoza and Tesar (1998), Altig et al. (2001), Garcia-Milà et al. (2010), Angelopoulos et al. (2012), and many others. To this literature, we should add papers on public debt consolidation (see Section 7).

6. See, for example, Masuch et al. (2018).

7. See European Commission (2014b, 2018b) and OECD (2017).

8. See, for example, de la Croix and Michel (2002) for a rich variety of overlapping generations models.

9. We have also allowed young households to borrow from, say, adults or old households to finance their spending on consumption and education. We report that the main results do not change. For various robustness checks, see Section 8.

10. As said, this is as in Acemoglu (2009, Chapter 9.6) and Coeurdacier et al. (2015).

11. This modeling is as in, for example, Bruce and Turnovsky (2013). Alternatively, we could assume that the labor income tax, τ_t^n, is imposed after we deduct social security contributions, namely, to have $(1-\tau_{t+1}^n)(1-\phi_{t+1})w_{t+1}l_{t+1}^m h_{t+1}^m$ in the adult's budget constraint [see e.g. Conesa and Garriga (2008)]. We report that our main results do not depend on the particular way we model the social security tax (results are available upon request).

12. See Quadrini and Ríos-Rull (2014), for various assumptions about the use of the assets left by the deceased households.

13. Following the related literature, individual human capital can be augmented by both private resources (time and expenditures) and public policy; see also, for example, Glomm and Ravikumar (1992), Kaganovich and Zilcha (1999), Blankenau and Simpson (2004), Blankenau (2005), and Arcalean and Schiopu (2010). Regarding the functional form used, see, for example, Arcalean and Schiopu (2010). Note that our functional form can nest several cases in this literature.

14. This specification (i.e. that individual human capital accumulation is an increasing function of both private and public spending on education) reflects the idea that public spending applies more to primary and secondary education, while private spending applies more to college education and on-the-job training.

15. Thus, the elasticity parameter, ν, is a measure of substitutability between the two types of spending, private and public. If $\nu = 1$, the two types become perfect substitutes, while if $\nu = 0$, the function turns to a Cobb–Douglas [see Stokey (1996)].

16. Since this probability does not depend on private decisions, like private spending on health or private income, there is nothing that the household can do to affect survival [see also, e.g. Quadrini and Ríos-Rull (2014)]. A generalization could be to assume $q(h_{t+1}^{hea}, s_t^{g^h})$, where the motion of household's health capital, h_{t+1}^{hea}, is $h_{t+1}^{hea} = (1-\delta^{hea})h_t^{hea} + B^{hea}(z_t^{hea})^{\nu}(s_t^{g^h})^{1-\nu}$, where z_t^{hea} is private spending on health.

17. As said, since the household takes policy as given, it also takes q_t as given. Besides, it does not internalize the link between social security pensions and social security taxes [see also, e.g. Conesa and Garriga (2008)]. Finally, it takes b_{t-1}^y as given.

18. We assume a PAYG system. See, for example, Docquier and Paddison (2003), Auerbach and Lee (2011), and Kaganovich and Zilcha (2012), for different social security systems. See also Section 8.

19. Technically speaking, the initial conditions of the predetermined state variables are those of the *status quo* solution.

20. As said above, as this paper is written, most of the data used here are not available beyond 2017.

21. For example, in the model above, the value of 0.13 for τ^n does not include the social security contributions, ϕ and ϕ^f, paid by workers and employers respectively. Setting s^{g^s} and ϕ^f at their data average values (0.115 and 0.15, respectively, over 2001–08), the value of ϕ that follows residually from the PAYG budget constraint is 0.08, which is close to its average value in the data over 2001–2008. Then, the implied total tax burden on labor income, $\tau^n + \phi + \phi^f$, is 0.36 which is also close to its data average value. Similarly, when we work with 2013–2017 data.

22. Inheritance taxes have fallen in most countries and nowadays constitute a very small share of total government revenues, less that 1%. See the anectodal evidence in *The Economist*, November 25th, 2017, pp. 21–23.

23. We report that our qualitative results are robust to fiscal changes of bigger, or smaller, magnitude.

24. This is modeled as follows. Consumption tax revenues as share of GDP in the *status quo* solution are $\tau^c \frac{n^y c^y + n^m c^m + qn^o c^o}{n^f y^f} = 0.193 \cdot 0.5022 = 0.1070$. In the reformed economy, this is reduced permanently by 1 pp. Then, along the transition of the reformed economy, the consumption tax rate follows from the equation $\tau_t^c \frac{n_t^y c_t^y + n_t^m c_t^m + qn_t^o c_t^o}{n_t^f y_t^f} = 0.0970$. We work similarly for the other tax rates.

25. In policy circles, it is usually claimed that alternative fiscal austerity measures bring in equivalent reductions in public debt so it does not matter which one is chosen. This is not correct of course: different fiscal instruments have different second-round effects.

26. However, in the robustness Section 8, where we study a self-financed PAYG system, we will also study the case in which ϕ becomes an endogenously determined variable.

27. When we study reforms, we work with the consolidated government budget constraint (22) meaning that when s^{g^s} changes, this is absorbed by changes in τ^c, or τ^n, or τ^k, or d_t^m, while ϕ_t remains at its *status quo* data value. This makes all policy experiments comparable. The special case in which changes in s^{g^s} are absorbed by changes in ϕ_t, as in equation (19), is studied in the robustness Section 8.

28. R2 and R4 are equivalent when we work with a consolidated government budget constraint (this is the case in the results of Sections 6 and 7). This equivalence does not hold, however, when the PAYG system is self-financed (see Section 8.4). Also notice that R3 and R4 are equivalent when the labor tax rate, τ^n, is the residual public financing instrument. In all these cases, this happens because τ^n, ϕ, and ϕ^f share the same tax base.

29. In these IRFs, savings are private savings as measured by $k_{t+1}^m + d_{t+1}^m$ in the adults' budget constraint in equation (3) above, while consumption is defined to be the weighted average of the consumption of young, adult, and old households in each period, where the weights are the respective population fractions as defined in the start of Section 3. IRFs for other variables are available upon request.

30. This is a well-recognized result: social security, via a PAYG system, decreases private saving and hurts capital formation. See, for example, Cooley and Soares (1999), Bouzahzah et al. (2002), Docquier and Paddison (2003), Krueger and Kubler (2006), and Soares (2006). Krueger and Kubler (2006) provide a quantitative evaluation of the pluses and minuses of a PAYG social security system, where the trade-off is between intergenerational risk-sharing and a lower capital stock. Here, we abstract from uncertainty and risk.

31. See Coeurdacier et al. (2015), Erceg and Lindé (2013), Philippopoulos et al. (2017a,b), Glomm et al. (2018), and many others for public debt consolidation policies in dynamic macroeconomic models. Philippopoulos et al. (2017b) also review the literature on feedback policy rules like the ones we use here. Alesina et al. (2019) use a VAR analysis and discuss several episodes of fiscal austerity.

32. See the beginning of Subsection 3.1 and equation (7) above for these parameter values.

33. In particular, we assume an AR(1) process for Ξ in the form $\Xi_t = \gamma^{\xi} \Xi_{t-1} + (1 - \gamma^{\xi})\Xi$, where we set $\gamma^{\xi} = 0.5$, $\Xi_0 = 0.6$ for the initial value and $\Xi = 0.75$ for the new steady-state value. We also assume an AR(1) process for n in the form $n_t = \gamma^n n_{t-1} + (1 - \gamma^n)n$, where we set $\gamma^n = 0.5$, $n_0 = 0$ for the initial value and $n = -0.02$ for the new steady state value. This parameterization gives values for the probability of reaching the old age, the increase in the share of the old in total population and the increase in the old-age dependency ratio close to those in the data as reported in the Ageing Report of the European Commission (2018c). Details are available upon request.

34. To save on space, we do not present IRFs here (they are available upon request). We report that they are similar to those in Figures 2 and 3.

35. For similar general equilibrium models with weak institutional quality, see, for example, Economides et al. (2007) and Angelopoulos et al. (2009).

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APPENDIX A: MACROECONOMIC EQUILIBRIUM

A.1. Market-clearing conditions

In the labor market, we have:

$$N_t^f l_t^f = N_t^m l_t^m h_t^m.$$

In the capital market, we have:

$$N_t^f k_t^f = N_{t-1}^m k_{t-1}^m.$$

https://doi.org/10.1017/S1365100520000036 Published online by Cambridge University Press

In the bond market, we have:

$$D_t = N_{t-1}^m d_{t-1}^m.$$

In the dividend "market", we have:

$$N_t^f \pi_t^f = N_{t-1}^m \pi_t^o.$$

In the bequest "market", we have:

$$N_t^y b_{t-1}^y = N_{t-1}^o [q_{t-1} b_{t-1}^o + (1 - q_{t-1})\, \Omega_{t-1}^o],$$

where

$$\Omega_{t-1}^o \equiv \left[1 - \delta^k + \left(1 - \tau_{t-1}^k\right) r_{t-1}\right] k_{t-2}^m + (1 + \rho_{t-1})\, d_{t-2}^m + \left(1 - \tau_{t-1}^k\right) \pi_{t-1}^o.$$

thus, the currently young inherit the bequests (chosen and unintended) of the previously old.

In the case of a 100% self-financed PAYG public pension system, its separate budget constraint is:

$$G_t^s = N_t^o s_t^o = \phi_t N_t^m w_t l_t^m h_t^m + \phi_t^f N_t^f w_t l_t^f. \qquad \textbf{(A.1)}$$

In the goods market, we have:

$$N_t^y c_t^y + N_t^y z_t^y + N_t^m c_t^m + N_t^o c_t^o + N_t^m k_t^m + G_t^c + G_t^h + G_t^e + G_t^i + G_t^d = N_t^m w_t l_t^m h_t^m + N_{t-1}^m \left(1 - \delta^k + r_t\right) k_{t-1},$$

so that (using the market-clearing conditions), we get the economy's resource constraint:

$$N_t^y c_t^y + N_t^y z_t^y + N_t^m c_t^m + N_t^o c_t^o + N_t^m \left[k_t^m - \left(1 - \delta^k\right) \frac{N_{t-1}^m}{N_t^m} k_{t-1}^m\right] + G_t^c + G_t^h + G_t^e + G_t^i + G_t^d = N_t^f y_t^f,$$

or, working with population shares, $n_t^y \equiv \frac{N_t^y}{N_t}$, $n_t^m \equiv \frac{N_t^m}{N_t}$ and $n_t^o \equiv \frac{N_t^o}{N_t}$:

$$n_t^y c_t^y + n_t^y z_t^y + n_t^m c_t^m + n_t^o c_t^o + n_t^m \left[k_t^m - \left(1 - \delta^k\right) \frac{n_{t-1}^m}{n_t^m} \frac{N_{t-1}}{N_t} k_{t-1}^m\right] + \left(s_t^{g^h} + s_t^{g^e} + s_t^{g^i} + s_t^{g^d} + s_t^{g^c}\right) n_t^f y_t^f = n_t^f y_t^f,$$

where public spending items in small letters denote per capita values and also we have:

$$n_t^y = \frac{(1+n)^2}{(1+n)^2 + (1+n) + q_t}, n_t^m = \frac{(1+n)}{(1+n)^2 + (1+n) + q_t} \equiv n_t^f,$$
$$n_t^o = \frac{q_t}{(1+n)^2 + (1+n) + q_t}, \frac{N_t}{N_{t-1}} = (1+n)\left(\frac{(1+n)^2 + (1+n) + q_t}{(1+n)^2 + (1+n) + q_{t-1}}\right).$$

A.2. Equilibrium system

We now present the equilibrium system at any time t for any feasible policy. In this equilibrium, households maximize welfare, firms maximize profits, all constraints are satisfied and all markets clear. This system is comprised of the following equations:

Young:

$$\chi_n \left(e_t^y\right)^\eta = \frac{\beta \left(c_{t+1}^m\right)^{-\sigma} \left(1-\tau_{t+1}^n-\phi_{t+1}\right) w_{t+1} l_{t+1}^m B\theta \left(e_t^y\right)^{\theta-1} \left[\gamma \left(z_t^y\right)^\nu + (1-\gamma)\left(\bar{G}_t^e+\lambda \bar{G}_t^h\right)^\nu\right]^{\frac{1-\theta}{\nu}}}{\left(1+\tau_{t+1}^c\right)}, \quad \textbf{(A.2a)}$$

$$\frac{\left(c_t^y\right)^{-\sigma}}{\left(1+\tau_t^c\right)} = \frac{\beta \left(c_{t+1}^m\right)^{-\sigma} \left(1-\tau_{t+1}^n-\phi_{t+1}\right) w_{t+1} l_{t+1}^m B \left(e_t^y\right)^{\theta} \gamma (1-\theta) \left[\gamma \left(z_t^y\right)^\nu + (1-\gamma)\left(\bar{G}_t^e+\lambda \bar{G}_t^h\right)^\nu\right]^{\frac{1-\theta}{\nu}-1}}{\left(z_t^y\right)^{1-\nu}\left(1+\tau_{t+1}^c\right)}, \quad \textbf{(A.2b)}$$

$$\left(1+\tau_t^c\right) c_t^y + z_t^y = \left(1-\tau_t^b\right) b_{t-1}^y, \quad \textbf{(A.2c)}$$

Adult:

$$\chi_n \left(l_t^m\right)^\eta = \frac{\left(c_t^m\right)^{-\sigma}\left(1-\tau_t^n-\phi_t\right) w_t h_t^m}{\left(1+\tau_t^c\right)}, \quad \textbf{(A.2d)}$$

$$\frac{\left(c_t^m\right)^{-\sigma}}{\left(1+\tau_t^c\right)} = \frac{\beta q_{t+1} \left(c_{t+1}^o\right)^{-\sigma} \left[\left(1-\delta^k\right)+\left(1-\tau_{t+1}^k\right) r_{t+1}\right]}{\left(1+\tau_{t+1}^c\right)}, \quad \textbf{(A.2e)}$$

$$\frac{\left(c_t^m\right)^{-\sigma}}{\left(1+\tau_t^c\right)} = \frac{\beta q_{t+1} \left(c_{t+1}^o\right)^{-\sigma} \left(1+\rho_{t+1}\right)}{\left(1+\tau_{t+1}^c\right)}, \quad \textbf{(A.2f)}$$

$$\left(1+\tau_t^c\right) c_t^m + k_t^m + d_t^m = \left(1-\tau_t^n-\phi_t\right) w_t h_t^m l_t^m, \quad \textbf{(A.2g)}$$

$$h_{t+1}^m = \left(1-\delta^h\right) h_t^y + B \left(e_t^y\right)^\theta \left[\gamma \left(z_t^y\right)^\nu + (1-\gamma)\left(\bar{G}_t^e+\lambda \bar{G}_t^h\right)^\nu\right]^{\frac{1-\theta}{\nu}}, \quad \textbf{(A.2h)}$$

Old:

$$\frac{\left(c_t^o\right)^{-\sigma}}{\left(1+\tau_t^c\right)} = \beta \chi_b \left(b_t^o\right)^{-\xi}, \quad \textbf{(A.2i)}$$

$$q_t \left(1+\tau_t^c\right) c_t^o + q_t b_t^o + (1-q_t)\,\Omega_t^o = \left[1-\delta^k+\left(1-\tau_t^k\right) r_t\right] k_{t-1}^m + \left(1-\tau_t^k\right)\pi_t^o + (1+\rho_t)\, d_{t-1}^m + q_t s_t^o, \quad \textbf{(A.2j)}$$

Government:

$$[s_t^{g^h}+s_t^{g^e}+s_t^{g^i}+s_t^{g^d}+s_t^{g^c}] n_t^f y_t^f + (1+\rho_t)\, n_{t-1}^m \frac{N_{t-1}}{N_t} d_{t-1}^m = n_t^m d_t^m + \tau_t^c \left(n_t^y c_t^y + n_t^m c_t^m + n_t^o c_t^o\right) + \tau_t^n n_t^m w_t l_t^m h_t^m + \tau_t^k n_{t-1}^m \frac{N_{t-1}}{N_t} r_t k_{t-1}^m + \tau_t^b n_t^y b_{t-1}^y + \tau_t^f n_t^f \left(y_t^f - w_t \frac{n_t^m}{n_t^f} l_t^m h_t^m\right), \quad \textbf{(A.2k)}$$

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$$n_t^o s_t^o = n_t^m \phi_t w_t l_t^m h_t^m + n_t^f \phi_t^f w_t \frac{n_t^m}{n_t^f} l_t^m h_t^m, \tag{A.2l}$$

$$\frac{N_{t+1}}{N_t} k_{t+1}^g = (1-\delta^g)\, k_t^g + s_t^{g^i} n_t^f y_t^f, \tag{A.2m}$$

$$s_t^{g^s} n_t^f y_t^f = n_t^o s_t^o, \tag{A.2n}$$

where, in the above equations, we use:

$$n_t^f y_t^f = A \left(n_{t-1}^m \frac{N_{t-1}}{N_t} k_{t-1}^m \right)^{\alpha_1} \left(n_t^m l_t^m h_t^m \right)^{\alpha_2} \left(k_t^g \right)^{1-\alpha_1-\alpha_2},$$

$$n_t^y b_{t-1}^y = n_{t-1}^o \frac{N_{t-1}}{N_t} \left[q_{t-1} b_{t-1}^o + (1-q_{t-1})\, \Omega_{t-1}^o \right].$$

$$\Omega_{t-1}^o \equiv \left[1-\delta^k + \left(1-\tau_{t-1}^k\right) r_{t-1} \right] k_{t-2}^m + (1+\rho_{t-1})\, d_{t-2}^m + \left(1-\tau_{t-1}^k\right) \pi_{t-1}^o,$$

$$\pi_t^o = \frac{\left(1-\tau_t^f\right)(1-\alpha_1-\alpha_2)\, n_t^f y_t^f}{n_{t-1}^m} \frac{N_t}{N_{t-1}}.$$

$$r_t = \frac{\left(1-\tau_t^f\right)\, \alpha_1 y_t^f}{k_t^f} = \frac{\left(1-\tau_t^f\right)\, \alpha_1 N_t^f y_t^f}{N_{t-1}^m k_{t-1}^m} = \frac{(1-\tau_t^f)\, \alpha_1 n_t^f y_t^f}{n_{t-1}^m k_{t-1}^m}, \frac{N_t}{N_{t-1}}$$

$$\left(1+\phi_t^f-\tau_t^f\right) w_t = \frac{\left(1-\tau_t^f\right)\, \alpha_2 n_t^f y_t^f}{n_t^m l_t^m h_t^m},$$

$$q_t \equiv \Xi \left(1 + \frac{s_t^{g^h}}{1+s_t^{g^h}} \right).$$

where $\bar{G}_t^e \equiv \frac{G_t^e}{N_t^y} = \frac{s_t^{g^e} N_t^f y_t^f}{N_t^y} = \frac{s_t^{g^e} n_t^f y_t^f}{n_t^y}$ and $\bar{G}_t^h \equiv \frac{G_t^h}{N_t^y} = \frac{s_t^{g^h} N_t^f y_t^f}{N_t^y} = \frac{s_t^{g^h} n_t^f y_t^f}{n_t^y}$.

We therefore have a second-order dynamic system of 14 equations, (A.2a)–(A.2n), in 14 endogenous variables. The 14 endogenous variables are $\left\{z_t^y, c_t^y, c_t^m, c_t^o, e_t^y, l_t^m, k_t^m, \rho_t, h_t^m, s_t^o, \phi_t, d_t^m, b_t^o, k_{t+1}^g\right\}_{t=0}^{\infty}$. This is the system in the case in which the public pension system is self-financed via adjustments in either ϕ_t or ϕ_t^f. This case, in which say ϕ_t adjusts to satisfy the budget constraint of the public pension system, is in the robustness Subsection 8.4. If this is not the case, meaning that there can be a difference between public spending on pensions and social security contributions to it (simply because, although both ϕ_t and ϕ_t^f are positive as in the data, neither of them is flexible enough to adjust to close the budget constraint of the public pension system), and that any such difference is financed out of the general government budget, then we replace (A.2k) and (A.2l) with the consolidated government budget constraint:

$$\left[s_t^{g^h} + s_t^{g^e} + s_t^{g^i} + s_t^{g^d} + s_t^{g^c}\right] n_t^f y_t^f + \left[n_t^o s_t^o - n_t^m \phi_t w_t l_t^m h_t^m - n_t^m \phi_t^f w_t l_t^m h_t^m\right]$$
$$+ (1+\rho_t)\, n_{t-1}^m \frac{N_{t-1}}{N_t} d_{t-1}^m$$
$$= n_t^m d_t^m + \tau_t^c \left(n_t^y c_t^y + n_t^m c_t^m + n_t^o c_t^o\right) + \tau_t^n n_t^m w_t l_t^m h_t^m + \tau_t^k n_{t-1}^m \frac{N_{t-1}}{N_t} r_t k_{t-1}^m$$
$$+ \tau_t^b n_t^y b_{t-1}^y + \tau_t^f n_t^f \left(y_t^f - w_t \frac{n_t^m}{n_t^f} l_t^m h_t^m\right), \qquad \textbf{(A.3)}$$

and, at the same time, we move both ϕ_t and ϕ_t^f to the category of the exogenously set variables. Thus, now we have 13 equations in 13 variables as explained in Subsection 3.3 in the main text.

The above two cases are polar. Namely, either one of ϕ_t or ϕ_t^f is fully flexible to close the budget constraint of the public pension system in each time period, or they both remain as in the data so that any differences between spending and revenues are absorbed by the consolidated budget constraint. Cases in between can be captured as follows: Say that only a fraction Φ of $n_t^o s_t^o$ (or equivalently of $s_t^{g^s} n_t^f y_t^f$) is self financed via adjustment of ϕ_t or ϕ_t^f, while the rest, namely $(1-\Phi) n_t^o s_t^o$ or equivalently $(1-\Phi) s_t^{g^s} n_t^f y_t^f$, is financed out of the general budget. Formally, we rewrite the budget constraint of the PAYG system as:

$$\Phi n_t^o s_t^o = n_t^m \phi_t w_t l_t^m h_t^m + n_t^f \phi_t^f w_t \frac{n_t^m}{n_t^f} l_t^m h_t^m, \qquad \textbf{(A.4)}$$

which is satisfied by endogeneity in ϕ_t or ϕ_t^f as in the first polar case above, while the consolidated government budget constraint is rewritten as:

$$\left[s_t^{g^h} + s_t^{g^e} + s_t^{g^i} + s_t^{g^d} + s_t^{g^c}\right] n_t^f y_t^f + (1-\Phi) n_t^o s_t^o + (1+\rho_t)\, n_{t-1}^m \frac{N_{t-1}}{N_t} d_{t-1}^m$$
$$= n_t^m d_t^m + \tau_t^c \left(n_t^y c_t^y + n_t^m c_t^m + n_t^o c_t^o\right) + \tau_t^n n_t^m w_t l_t^m h_t^m + \tau_t^k n_{t-1}^m \frac{N_{t-1}}{N_t} r_t k_{t-1}^m$$
$$+ \tau_t^b n_t^y b_{t-1}^y + \tau_t^f n_t^f \left(y_t^f - w_t \frac{n_t^m}{n_t^f} l_t^m h_t^m\right). \qquad \textbf{(A.5)}$$

APPENDIX B: FEEDBACK POLICY RULES USED FOR PUBLIC DEBT CONSOLIDATION

As said in the main text, to model public debt consolidation, we follow most of the related literature by assuming that the fiscal instruments react to the gap between the public debt-to-GDP ratio and a policy target value. In particular, we assume

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the following feedback policy rules for the consumption tax rate, the labor income tax rate, the capital income tax rate and the profit tax rate respectively:

$$\tau_t^c = \rho^c \tau_{t-1}^c + (1-\rho^c)\tau^c + \gamma^c \left(s_t^d - s^{d*}\right), \tag{B.1}$$

$$\tau_t^n = \rho^n \tau_{t-1}^n + (1-\rho^n)\tau^n + \gamma^n \left(s_t^d - s^{d*}\right), \tag{B.2}$$

$$\tau_t^k = \rho^k \tau_{t-1}^k + (1-\rho^k)\tau^k + \gamma^k \left(s_t^d - s^{d*}\right), \tag{B.3}$$

$$\tau_t^f = \rho^f \tau_{t-1}^f + (1-\rho^f)\tau^f + \gamma^f \left(s_t^d - s^{d*}\right), \tag{B.4}$$

where $s_t^d \equiv \frac{n_t^m d_t^m}{n_t^f y_t^f}$ denotes the current debt-to-GDP ratio, the debt target, s^{d*}, is set at 0.6 which is the criterion of the Maastricht Treaty, $0 \leq \rho^i \leq 1$ are autoregressive parameters and $\gamma^i \geq 0$ are feedback policy coefficients where $i \equiv (c, n, k, f)$. As a baseline parameterization, we set ρ^i at zero and γ^i at 3, which imply that the debt target is reached in one period (25 years). We report that we have experimented with other parameter values and the main results do not change, although these baseline values ensure robust results for R13 across all experiments. See, for example, Philippopoulos et al. (2017a,b) for debt consolidation and feedback policy rules in infinite-horizon representative agent models.

APPENDIX C: ADDING WEAK PROPERTY RIGHTS

In this appendix, we augment the baseline model to allow for weak property rights. We also allow public spending on defense and public-order safety to contribute to the protection of these rights.

As said in the text, in each period, each firm can appropriate only a fraction $0 < p_t \leq 1$ of its output produced, y_t^f. The rest, $(1 - p_t)\, y_t^f$, can be taken away by adult households. Thus, p_t denotes the degree of protection of property rights in the economy. Similarly to the modeling of the survival probability when old, we assume that p_t depends only on public expenditure on defense and public-order safety as a share of GDP, $s_t^{g^d}$. In particular, the degree of property rights is denoted as $p\left(s_t^{g^d}\right)$, where $p\,(.)$ is increasing and concave. For convenience, we again use the functional form:

$$p_t = p\left(s_t^{g^d}\right) = \Gamma\left(1 + \frac{s_t^{g^d}}{1 + s_t^{g^d}}\right), \tag{C.1}$$

where the parameter $0 < \Gamma < 1$ is calibrated so as to capture the degree of protection of property rights in the data.

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The profit function of each firm is:

$$\pi_t^f \equiv p_t y_t^f - \left(1+\phi_t^f\right) w_t l_t^f - r_t k_t^f - \tau_t^f \left(p_t y_t^f - w_t l_t^f\right). \quad \textbf{(C.2)}$$

The variable p_t is taken as given by the firm when it solves its optimization problem. The first-order conditions are now:

$$r_t = \frac{\left(1-\tau_t^f\right) \alpha_1 p_t y_t^f}{k_t^f}, \quad \textbf{(C.3a)}$$

$$\left(1+\phi_t^f-\tau_t^f\right) w_t = \frac{\left(1-\tau_t^f\right) \alpha_2 p_t y_t^f}{l_t^f}, \quad \textbf{(C.3b)}$$

so that each firm's net profit is now:

$$\pi_t^f = \left(1-\tau_t^f\right)(1-\alpha_1-\alpha_2) p_t y_t^f, \quad \textbf{(C.4)}$$

Regarding households, the budget constraint of the adult is now:

$$\left(1+\tau_t^c\right) c_t^m + k_t^m + d_t^m = \left(1-\tau_t^n-\phi_t\right) w_t h_t^m l_t^m + \frac{(1-p_t) N_t^f y_t^f}{N_t^m}, \quad \textbf{(C.5)}$$

where $\frac{(1-p_t)N_t^f y_t^f}{N_t^m}$ is the extra income extracted by each adult in the case of weak property rights. This extra term is taken as given by the household when it solves its optimization problem.

Therefore, in the final equilibrium system, we use:

$$\pi_t^o = \frac{\left(1-\tau_t^f\right)(1-\alpha_1-\alpha_2)\, n_t^f p_t y_t^f}{n_{t-1}^m} \frac{N_t}{N_{t-1}}, \quad \textbf{(C.6a)}$$

$$r_t = \frac{\left(1-\tau_t^f\right) \alpha_1 n_t^f p_t y_t^f}{n_{t-1}^m k_{t-1}^m} \frac{N_t}{N_{t-1}}, \quad \textbf{(C.6b)}$$

$$\left(1+\phi_t^f-\tau_t^f\right) w_t = \frac{\left(1-\tau_t^f\right) \alpha_2 n_t^f p_t y_t^f}{n_t^m l_t^m h_t^m}, \quad \textbf{(C.6c)}$$

$$\left(1+\tau_t^c\right) c_t^m + k_t^m + d_t^m = \left(1-\tau_t^n-\phi_t\right) w_t h_t^m l_t^m + \frac{(1-p_t) n_t^f y_t^f}{n_t^m}. \quad \textbf{(C.6d)}$$

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APPENDIX D: A FULLY FUNDED (FF) PUBLIC PENSION SYSTEM

In this appendix, we provide a brief sketch of the model in the case of a fully funded public pension system. Say that the government collects SSCs from employees/adults at time $t+1$ (for notational simplicity, here we assume away SSCs paid by firms), invests them in physical capital with a return $(1-\delta^k+r_{t+1})$ and then distributes the resulting amount to the same individuals when they reach the old age at $t+2$. Thus, here we consider the best possible case where all related funds are invested in capital [see also Acemoglu (2009, chapter 9.5)].

The budget constraint of the fully funded social security system is now (as said, we do not include SSCs paid by firms here):

$$n_t^o s_t^o = (1-\delta^k+r_t)\phi_{t-1} n_{t-1}^m w_{t-1} l_{t-1}^m h_{t-1}^m.$$

In the capital market (since all social security funds are invested in capital), the market-clearing condition is now:

$$n_t^f k_t^f = n_{t-1}^m k_{t-1}^m + \phi_{t-1} n_{t-1}^m w_{t-1} l_{t-1}^m h_{t-1}^m.$$

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