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Policy reforms and growth in computable OLG economies ☆

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Abstract

We build a computable general equilibrium model with overlapping generations of agents and an endogenous growth specification à la Lucas. Two main issues are addressed: (i) to what extent does endogenous growth play a significant role in the face of policy reforms and (ii) are the simulation results robust to various calibrations of the production function of human capital. In this purpose, we simulate four large policy changes and compare the predictions with endogenous growth (under various parameter sets) to those with exogenous growth. If endogenous growth is important when examining the effects of education reform, it does not really matter with pension reforms and plays a minor role in the debt repayment scenario. These results are very robust to calibration.

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1. Introduction

Since the late 1970s and the failures of Keynesian macroeconometric models, the macroeconomic theory has been deeply reshaped around the microfoundations of individual behaviors. In terms of policy evaluation, most economists now recognize that there are strong reasons to use calibrated, general equilibrium models as the principal toolkit of analysis. Two different setups emerged from that literature: (1) The propagation of productivity shocks has been explored in real business cycles (RBC) models extending the theoretical infinite horizon model of Cass–Koopmans–Ramsey; (2) The study of public finance shocks (implying intergenerational considerations) has been explored in computable, overlapping generations (OLG) model initiated by Auerbach and Kotlikoff (1987) and extending the basic framework of Allais–Samuelson–Diamond. These two setups build on the neo-classical one-sector growth model but emphasize the microeconomic structure of household's decision. However, as in the traditional Solow model, they are based on the highly strong assumption that the pace of long-run growth is exogenous.

At the same time, a large theoretical literature discredited the assumption of exogenous long-run growth and examined the source of productivity changes. Although the basic intuition of the endogenous growth literature dates back to the 1960s, most analytical models were developed in the 1980s, emphasizing the role of human capital accumulation (Lucas, 1988), learning by doing (Romer, 1986), public infrastructures (Barro, 1990), or expenditures in research and development (Grossman and Helpman, 1991) on the rate of growth. Usually, these models are based on the existence of externalities associated to the engines of growth. It follows that the market equilibrium generally differs from the social optimum. It is then possible to derive the government intervention that leads to a Pareto-efficient solution.

In endogenous growth models, tax reforms are likely to have an impact on the rate of economic growth. A number of papers have investigated this question in an endogenous growth setting, providing ambiguous results for comparable policy changes. On the one hand, Lucas (1990) predicts very small growth effects while, on the other hand, Jones et al. (1993) find very large responses. Stockey and Rebelo (1995) argue that large growth effects of tax reforms are difficult to reconcile with the post-war experience of the United States (where the long-run growth trend has been constant despite drastic increases in the tax rates). As results seems to be very sensitive to the choice of some parameters (as the elasticities of substitution), they recommend the use of small elasticities.

The sensitivity of growth rates to policy changes can also be important when intergenerational transfers (pensions, debts etc.) are involved. On the one hand, if pension reforms or debt reduction induce reasonable growth effects, the exogenous growth assumption is likely to be restrictive. But on the other hand, if such reforms lead to excess changes in the growth rate, this would seriously reduce the credibility of models displaying endogenous growth. In this paper, we address this issue with an applied general equilibrium version of the OLG model with an endogenous growth specification à la Lucas (1988). Human capital investment made by agents when young is the engine of growth. Since Auerbach and Kotlikoff's seminal book, several examples of OLG exogenous growth applications can be found in the literature.[2] Few of them endogenize the rate of productivity growth. One exception is the paper of Fougère and Mérette (1999) which uses a similar growth specification to ours but allows for education investment in each period of life and does not take into account the huge government intervention in education financing. Another exception is the paper of Docquier and Michel (1999) providing a simulation exercise on the basis of a very simple model with three periods of life.

Two of the biggest problems arising with numerical endogenous growth models are the choice of a human capital technology specification and the calibration of its parameters. Thanks to numerous economic studies, there is a large consensus on the production function of consumption and investment goods; there is, however, no real evidence on the choice of the production function of human capital. We opt for a simple specification in which the rate of growth of human capital is a concave function of the time invested in education. We then calibrate the parameter of this function to reproduce the long-run aggregates observed in most European countries.

Our purpose here is to develop a larger computable model with a complete description of the public finance aggregates and to compare configurations with endogenous growth to exogenous growth specifications. More specifically, we address the two following questions: (1) To what extent does endogenous growth play a significant role in the face of external shocks? (2) Are the simulation results robust to various calibrations of the production function of human capital?

We answer these questions by simulating the macroeconomic effects of very large policy changes as debt repayment, a rise in the retirement age or the abolition of social security and education subsidies. Our results reveal that the sense and the magnitude of the macroeconomic changes are usually robust to the calibration. Endogenous growth does not seem to play a major role except for policy reforms in terms of education subsidies. This result is obtained

[2] Auerbach et al. (1989), Börsch-Supan (1996) and Hviding and Mérette (1998) on various OECD countries, Chauveau and Loufir (1996) on the Japan economy, Broer et al. (1994) and Broer (1999) on the Dutch economy, Docquier et al. (1999) on Belgium and Miles (1999) on UK. These models extend the initial model by incorporating several features as trade openness and multi-sectoral production sector in Broer et al. (1994), generational accounting in Fehr and Kotlikoff (1995), life uncertainty and generational accounting in Docquier et al. (1999) or intragenerational considerations in Kotlikoff et al. (1999).

despite a relatively high elasticity of substitution in the utility function, which contradicts the conjecture of Stockey and Rebelo (1995). As in Hendricks (1999), the small impact of fiscal reform can easily be interpreted by the large tax deductibility of the investment in the growth source (i.e. human capital). Since most tax reforms do not strongly distort the private incentive to accumulate human capital, they induce small growth changes. Policy reforms only generate large growth effects when they significantly alter the private burden of education.

The rest of this paper is organized as follows. Section 2 depicts the model. Section 3 presents the calibration procedure and the scenarios. Results are given in Section 4. Finally, Section 5 concludes the paper.

2. A computable OLG model

Our model depicts a closed economy with overlapping generations of adults. Agents are homogenous within generations and live for six periods of life (i.e. from age 18 to age 78), each of them representing 10 years. The size of generation-t increases over time:

$$N_t = m_t N_{t-1},$$

where m_t is one plus the population growth rate between generation $t-1$ and t.

We consider an endogenous growth specification à la Lucas. In the first period of life, young adults inherit a given level of human capital and have the possibility to increase it by devoting a part of their time to human capital formation (i.e. education). In addition to the private effect of education, there are two types of externality:

- an intergenerational externality: the human capital investment of the young at time t is partly transmitted to the next generation;
- an intratemporal externality: the average level of human capital at time t increases the contemporaneous productivity of each factor of production.

Our model also contains a public sector and firms. Let us now describe the behavior of each agent.

2.1. Households behavior

The representative individual reaching age 18 at time t maximizes an inter-temporal utility function depending on the sequence of consumption expenditures over his whole lifetime. We assume an additively separable

CES form:

$$U_t = \sum_{j=1}^{6} \gamma^{j-1} \frac{[c_{t+j-1}^j]^{1-1/\sigma} - 1}{1 - 1/\sigma}, \tag{1}$$

where j refers to the jth period of life, $\gamma \in (0,1)$ is the relative weight given to the next period instantaneous utility (a measure of time preference) and $\sigma \in \mathbb{R}_+$ measures the elasticity of inter-temporal substitution.

Assuming perfect credit market, the inter-temporal budget constraint requires the equality between the discounted value of lifetime expenditures and the discounted value of lifetime income. If r_{t+1} denotes the interest rate between the dates t and $t+1$,

$$R_t^{t+j} = \prod_{s=t+1}^{t+j} \frac{1}{1+r_s}, \quad \forall j \in \mathbb{N}$$

is the appropriate discount factor applied to $t+j$ income and spending. The present value of expenditures is given by

$$E_t = \sum_{j=1}^{6} c_{t+j-1}^j (1 + \tau_{t+j-1}^{\mathrm{c}}) R_t^{t+j} \tag{2}$$

while the present value of the life-cycle income is given by

$$W_t = \sum_{j=1}^{6} ((1 - \tau_t^{\mathrm{w}}) w_{t+j-1} l_{t+j-1}^j h_{t+j-1}^j + T_{t+j-1}^j) R_t^{t+j}, \tag{3}$$

where τ_t^{c} is the consumption tax rate at time t, τ_t^{w} is the proportional rate of tax on labor income, w_t denotes the gross wage rate per efficiency unit of labor at time t, l_{t+j-1}^j measures the labor supply of generation t at age j, h_{t+j-1}^j is the level of human capital at age j and T_{t+j-1}^j stands for the public transfers received at age j.

For each generation-t member, the sequence of labor supply is given by

$$(l_t^1, l_{t+1}^2, l_{t+2}^3, l_{t+3}^4, l_{t+4}^5, l_{t+5}^6) \equiv (1 - e_t, 1, 1, 1, 1 - \alpha_{t+4}, 0), \tag{4}$$

where e_t measures the (endogenous) time invested in education in the first period of life and α_{t+4} $(0 < \alpha_{t+4} < 1)$ stands for the (exogenous) time spent in retirement in the fourth period of life (between age 58 and age 68). Labor supply is thus determined exogenously except for the time invested in human capital formation when young (between age 18 and age 28).

In the spirit of Lucas (1988), the time invested in education improves the efficiency of labor. The sequence of human capital for the generation born in t is endogenously given by

$$\begin{aligned}&(h_t^1, h_{t+1}^2, h_{t+2}^3, h_{t+3}^4, h_{t+4}^5, h_{t+5}^6) \\ &\quad \equiv (1, \theta_2\varphi(e_t), \theta_3\varphi(e_t), \theta_4\varphi(e_t), \theta_5\varphi(e_t), 0) \times h_t^1,\end{aligned} \tag{5}$$

where θ_i (i=2,...,5) are parameters measuring the relative productivity at age i compared to the one at age 1. It combines learning by doing effects as well as human capital depreciation with age. Variable h_t^1 measures the inherited human capital of the generation reaching age 18 at t. The function $\varphi(e_t)$ is a common training technology transforming educational investment into labor efficiency. It plays a crucial role in the determination of the economic growth rate. We assume here the simple following form

$$\varphi(e_t) \equiv 1 + \xi e_t^{\psi}, \tag{6}$$

where $\psi \in (0,1)$ and $\xi \in \mathbb{R}_+$ are two parameters.

Finally, the vector of public transfer per age is given by

$$(T_t^1, T_{t+1}^2, T_{t+2}^3, T_{t+3}^4, T_{t+4}^5, T_{t+5}^6) \equiv (v_t e_t(1-\tau_t^{\mathrm{w}})w_t h_t^1, 0, 0, 0, \alpha_{t+4} p_{t+4}, p_{t+5}), \tag{7}$$

where v_t is a public subsidy rate on the individual education cost (a fraction v_t of the opportunity cost of education is covered by government subsidies) and p_t measures the social security benefit allocated at full-time retirees at time t. Agents who are partly at work receive a proportion of the full benefit.

The inter-temporal budget constraint of the household is

$$E_t \leqslant W_t. \tag{8}$$

The maximization program of the generation born in t consists of maximizing the utility function (1) subject to the budget constraint (8) given the sequences of labor supply, human capital and public transfer defined above.

Since there is no disutility of labor, the problem of the household is separable. We can first maximize lifetime income with respect to educational investment. Second, we can find the optimal consumption profile by maximizing utility.

Maximizing with respect to the educational investment gives the following result:

$$e_t^* = \left(\xi\psi \sum_{j=2}^{6} \frac{(1-\tau_{t+j-1}^{\mathrm{w}})w_{t+j-1} l_{t+j-1}^j \theta_j}{(1-\tau_t^{\mathrm{w}})w_t(1-v_t)} R_t^{t+j} \right)^{1/(1-\psi)}. \tag{9}$$

The educational investment increases with the discounted level of future net wages and with the public subsidy rate but decreases with the current net wage, which represents an opportunity cost.

Maximizing utility with respect to the levels of consumption determines the law of motion of consumption expenditures over the lifetime:

$$c_{t+j-1}^j = \left[\frac{1+\tau_{t+j-2}^{\mathrm{c}}}{1+\tau_{t+j-1}^{\mathrm{c}}} \gamma R_{t+j-2}^{t+j-1} \right]^{\sigma} c_{t+j-2}^{j-1}, \quad \forall j = 2,\dots,6. \tag{10}$$

Substituting these results in the inter-temporal budget constraint (8) gives the optimal level of consumption when young.

Eqs. (8)–(10) completely determines the optimal behavior of generation-t members. It is also possible to derive the level of asset at the end of each period. One obtains

$$a^j_{t+j-1} = a^{j-1}_{t+j-2} R^{t+j-1}_{t+j-2} + (1-\tau^{\mathrm{w}}_{t+j-1}) w_{t+j-1} l^j_{t+j-1} h^j_{t+j-1} \\ + T^j_{t+j-1} - c^j_{t+j-1}(1+\tau^{\mathrm{c}}_{t+j-1}), \tag{11}$$

where a^j_{t+j-1} denotes individual asset at the end of age j. Of course, it is always optimal to die with no asset and a^6_t is always equal to zero.

2.2. The productive sector

At each period of time, a representative firm uses labor (L_t, in efficiency unit) and physical capital (K_t) to produce a composite good (Y_t). As in Lucas (1988), we assume a Cobb Douglas production function where the average stock of human capital per worker ($\bar{h}_t$) influences the aggregated level of productivity:

$$Y_t = AK^\beta_t L^{1-\beta}_t \bar{h}^\varepsilon_t, \tag{12}$$

where β measures the share of capital income in the national product, ε is a parameter of intratemporal externality, A is an exogenous scale parameter and $\bar{h}_t$ is the average stock of human capital of agents at work.

Labor supply in efficiency unit is obtained by summing up individual amounts:

$$L_t = \sum_{j=1}^{5} N_{t-j+1} l^j_t h^j_t \tag{13}$$

so that the average stock of human capital at time t is obtained by dividing labor supply in efficiency unit by the physical quantity of workers:

$$\bar{h}_t = \frac{L_t}{\sum_{j=1}^{5} N_{t-j+1} l^j_t}. \tag{14}$$

The firm behaves competitively on the factor markets. The profit maximization conditions require the equality of the marginal productivity of each factor to its rate of return. They may thus be written

$$w_t = A(1-\beta)K^\beta_t L^{-\beta}_t \bar{h}^\varepsilon_t, \tag{15}$$

$$\delta + r_t = A\beta K^{\beta-1}_t L^{1-\beta}_t \bar{h}^\varepsilon_t, \tag{16}$$

where $\delta \in (0,1)$ is the capital depreciation rate.

2.3. The government

The government issues bonds and levies taxes on labor earnings and individual consumption expenditures to finance its spending. Four types of public expenditures are distinguished: education subsidies, social security benefits, public consumption and the interests on public debt. The government budget constraint may be written as

$$\tau_t^{\mathrm{w}} w_t L_t + \tau_t^{\mathrm{c}} C_t + D_{t+1} = N_t v_t e_t (1 - \tau_t^{\mathrm{w}}) w_t h_t^1 + (N_{t-4}\alpha_t + N_{t-5}) p_t$$
$$+ G_t + (1 + r_t) D_t, \qquad (17)$$

where D_t denotes public debt at the beginning of period t, G_t and C_t respectively, measures aggregated public consumption and private consumption at time t. They can be defined as

$$G_t = \sum_{j=1}^{6} N_{t-j+1} G_t^j, \qquad (18)$$

$$C_t = \sum_{j=1}^{6} N_{t-j+1} c_t^j, \qquad (19)$$

where G_t^j is the amount of public consumption per age-j agent at time t. We assume that the ratio of public spending to the appropriate index of human capital is constant:

$$\frac{G_t^j}{h_t^{1(1-\beta+\varepsilon)/(1-\beta)}} = g^j. \qquad (20)$$

This keeps constant the share of public spending in output in the long run.

Several scenarios can be simulated. The government budget constraint can be balanced by tax adjustments, expenditure adjustments or changes in the public debt. In our basic scenario, the government budget constraint (17) is yearly adjusted through wage income tax changes in order to keep the debt—output ratio constant at a given level d:

$$\frac{D_{t+1}}{Y_t} = d, \quad \forall t. \qquad (21)$$

2.4. The dynamics

The dynamics of our economy is governed by the evolution of the stocks of human capital and physical capital over time. The stock of physical capital at time $t+1$ is determined by the quantity of assets accumulated by households minus the public debt:

$$K_{t+1} = \sum_{j=1}^{5} N_{t-j+1} a_t^j - D_{t+1}. \qquad (22)$$

The human capital accumulation plays a crucial role in our model. It is assumed that the inherited level of human capital of generation-t members, h_t^1 is equal to the level of human capital acquired by adults of the previous generation (not taking into account the age-specific correction θ_2). One can thus write that

$$h_t^1 = h_{t-1}^1(1 + \xi e_{t-1}^{\psi}). \tag{23}$$

2.5. The competitive equilibrium

When the economy starts at $t = 0$, six generations are alive. The one born at $t = 0$ will live for six periods. There are also five "old" generations each endowed with a level of assets and human capital. The generation born at $t = -5$ reaches age 6 at time 0 and its stock of human capital is 0. The initial conditions are thus: $(h_{-1}^1, h_{-1}^2, h_{-1}^3, h_{-1}^4, h_{-1}^5)$ and $(a_{-1}^1, a_{-1}^2, a_{-1}^3, a_{-1}^4, a_{-1}^5)$. The initial stock of capital K_0 is obtained by

$$K_0 = \sum_{j=1}^{5} N_{-j} a_{-1}^j - D_0,$$

where D_0 is the inherited debt in period 0. The competitive equilibrium can thus be characterized as follows:

Given the initial conditions $(K_0, D_0), (a_{-1}^j, h_{-1}^j)_{j=1,\dots,5}$, the exogenous population $(N_t)_{t \geqslant 0}$ and the exogenous policy variables d, $(g^j)_{j=1,\dots,6}$ and $(\tau_t^{\mathrm{c}}, p_t, \alpha_{t+4}, v_t, \tau_t^{\mathrm{w}})_{t \geqslant 0}$, a competitive equilibrium is characterized by

- individual positive quantities $(c_t^j, e_t, h_t^j, T_t^j, G_t^j, l_t^j, a_t^j)_{t \geqslant 0,\ j=1,\dots,6}$,
- aggregate positive quantities $(Y_t, L_t, K_{t+1}, \bar{h}_t, G_t, C_t, D_t)_{t \geqslant 0}$, and
- prices $(w_t, r_t)_{t \geqslant 0}$

such that Eqs. (4), (5), (7)–(23) hold.

3. Calibrating the model

The economic environment depicted above allows us to simulate the transitory and long-run effects of policy changes and other exogenous shocks. This simulation exercise requires calibrating the model, i.e. choosing the values of the parameters and exogenous variables so as to match a series of empirical moments computed on European data. It is often argued that one of the main disadvantages of applied general equilibrium models is the difficulty to calibrate some parameters. Simulation results are thus characterized by large confidence intervals. This is especially true in endogenous growth models since there is no real consensus on the parameters of the human capital formation technology. Our calibration procedure proceeds in two steps. First we

Table 1
Exogenous variables and fixed parameters

Exogenous variables			Fixed parameters		
Pension transfer	p	3.000	Total factor productivity	A	8
Share of leisure at age 56–68	α	0.200	Share of capital income	β	0.29
Debt to GDP ratio	d	0.050	Inter-temporal elast. of subst.	σ	1.500
Public spending at age 18–28	g^1	2.093	Capital depreciation rate	δ	0.400
Public spending at age 28–38	g^2	2.552	Relative efficiency at age 28–38	θ_2	1.390
Public spending at age 38–48	g^3	1.991	Relative efficiency at age 38–48	θ_3	1.760
Public spending at age 48–58	g^4	2.705	Relative efficiency at age 48–58	θ_4	1.930
Public spending at age 58–68	g^5	2.603	Relative efficiency at age 58–68	θ_5	1.850
Public spending at age 68–78	g^6	2.114	Lucas externality parameter	ε	0.100
Consumption tax rate	τ^c	0.120	Population growth rate	m	1.000
			Time preference	γ	0.840

fix the exogenous variables and the parameters on which a consensus exists in the literature. We then consider three scenarios for the parameters influencing the educational investment and the rate of growth of human capital. This sensitivity analysis will allow us to assess the robustness of the results to the choice of this second set of parameters.

The first step is summarized in Table 1. We consider a constant population size ($m=1$). The social security system is such that the pension benefit amounts to 50% of the net wage of worker and agents spend 4/5% of their time at work between age 58 and age 68. The first value represents the average benefit ratio observed in most European countries and the second value corresponds to a retirement age of about 65. The debt–GDP ratio is set at 0.05, which is slightly below the Maastricht criterion of 0.06. Other public expenditures are split per age group using the French study on generational accounting data of Crettez et al. (1998). Age profiles are computed using data from the French household survey "Le budget des ménages en 1995".[3] Public consumption is assumed to be constant per individual. The consumption tax rate is set to 12%. The share of capital income in national revenue amounts to 29%: this corresponds to the average share observed these last 20 years. The age component of the productivity profile is calibrated using the quadratic equation used by Miles (1999). This is an interpolation of an annual productivity function ($\theta_{\text{age}} = 0.05 \times age - 0.0006 \times age^2$). The rate of depreciation of the stock of capital is 40%. This roughly corresponds to an annual rate of 4% observed in industrialized economies. The parameter of human capital externality à la Lucas is set to 0.1.[4] Finally, the rate of time

[3] The g^i are expressed as public spending divided by the term $(h_t^1)^{(1+\varepsilon-\beta/1-\beta)}N_t$ which grows at the same rate as output.

[4] Even if there is no consensus on this value, a sensitivity analysis shows that this is not a crucial parameter in our model.

Table 2
Calibration under three different scenarios: parameters

Parameters		Scenario 1	Scenario 2	Scenario 3
Education parameter	ψ	0.10	0.20	0.30
Education parameter	ξ	0.23	0.27	0.31
Education subsidy rate	v	0.75	0.52	0.33

preference is set at $0.84 = 0.983^{10}$. We use a high inter-temporal elasticity of substitution (1.5). The econometric literature offers a wide range of estimates for this parameter (from 0.05 to values above 1). Since there is no altruistic motive in our model, we use a high value of elasticity, combined with a low rate of time preference, to generate realistic aggregate saving rates, wealth profiles per age and interest rates.

In the second step, we consider three alternative scenarios for the parameters of the production function of human capital and for the subsidy rate to education—parameters for which there is no consensus. Even if it can be argued that the monetary cost of education is largely subsidized, the opportunity cost of education is generally not subsidized. In Docquier and Michel (1999) these two types of cost are distinguished so that different subsidy rates can be used. In this model we use an aggregate concept of education cost so that there is no a priori evidence on the choice of a realistic subsidy rate.

Our aim is to obtain an annual growth rate of 1.8%, an annual rate of interest around 4.6%, an income tax rate slightly below 30% and an educational investment around 20%. This last value is compatible with school attendance ratio between age 18 and age 28 observed in European countries. We let the parameter of decreasing return on educational investment (ψ) vary between 0.1 to 0.3. To keep a realistic growth rate of 1.8%, we need to change the scale parameter in the human capital formation technology (ξ). Its value in the three scenarios is given in Table 2 and the corresponding production functions are plotted in the left panel of Fig. 1. Although initial growth rates are identical across scenarios (this is the purpose of our calibration strategy), their sensibility to human capital decisions are very different—the slope at the equilibrium greatly varies. Growth reactions to exogenous shocks affecting the individual education decision can thus be expected to differ.

These parameter changes modify in turn the optimal investment of households. We then modify the rate of subsidy (v) to maintain the target level of human capital investment.[5] This partly compensates the change in the ψ parameters in the optimal reaction of households. We have represented in the right panel of Fig. 1 the optimal choice described by (9) as a function of

[5] Note that, although human capital and financial investments are strongly interrelated, we do not have to modify the rate of time preference so as to keep a realistic value for the interest rate.

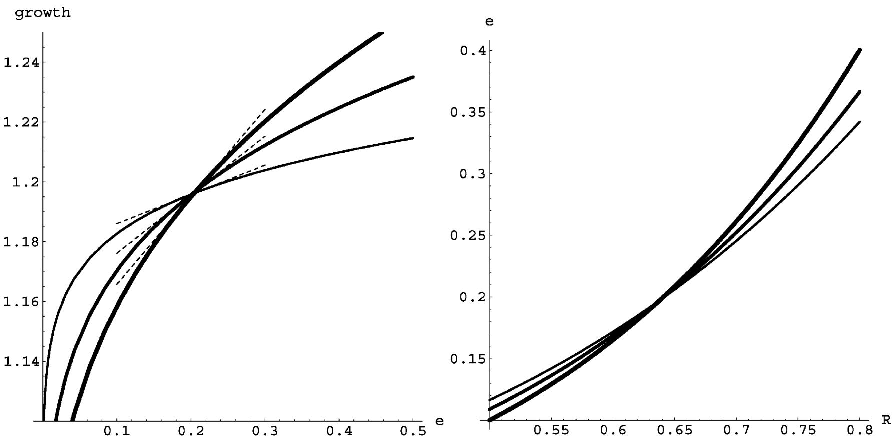

Fig. 1. The three scenarios.

Table 3
Calibration under three different scenarios: endogenous variables

Steady state values	Scenario 1 (%)	Scenario 2 (%)	Scenario 3 (%)
Annual growth rate	1.80	1.80	1.80
Annual interest rate	4.59	4.64	4.68
Tax rate on wages	29.6	29.3	29.1
Private consumption–output ratio	61.0	61.1	61.1
Public consumption–output ratio	20.2	20.3	20.4
Replacement ratio	50.7	50.6	50.5
Time devoted to education	19.3	20.2	21.2

R at steady state. Here, the difference between the three scenarios is small. Hence, exogenous shocks affecting education decisions through the interest factor only can thus be expected to yield the same quantitative effect in the three scenarios.

Looking at Table 3, it comes out that these parameter sets give very similar steady states. The rates of growth, the rates of interest and the wage income tax rates are roughly identical. On the aggregate, it is worth noticing that the share of private consumption and the shares of public consumption correspond to the ones observed in most European countries.

To perform the simulations we choose to use an algorithm that preserves the non-linear nature of the model. We follow the methodology proposed by Boucekkine (1995) for saddle-point trajectories of non-linear deterministic models and implemented by Juillard (1996) in the program Dynare. The infinite horizon problem is approximated by a horizon of 30 periods. Increasing the simulation horizon further does not modify the results. Only the first 12

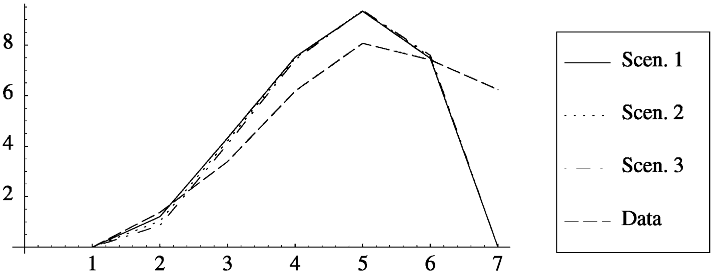

Fig. 2. Asset profile per age.

periods are displayed since the steady state is almost attained after 12 periods. Note moreover that it is easy to determine whether the convergence of the algorithm is due to the existence of saddle-point trajectory or not. Indeed, the algorithm is characterized by an explosivity property in the case where an infinity of stable solutions exist (Boucekkine and Le Van, 1996).[6] The implementation of these tests allows us to conclude that our scenarios provide three plausible steady states that are locally stable in the saddle-point sense.

To build an exogenous growth model that can be compared to the endogenous one, we take the same calibration as in scenario 2 but assume that households do not choose e_t optimally. Instead, e_t is kept constant (at its steady state value in scenario 2). This slight modification removes the source of endogenous growth without affecting the calibration.

Coming back to the micro-foundations, Fig. 2 compares the individual asset age-profiles obtained in the three scenarios (dashed line) with the ones observed in France (solid line). Wealth accumulation is mainly effective after age 40. We have the usual result that the life-cycle model does not provide a good description of saving behavior at old age since it predicts a sharp decline in saving after retirement age (no bequest motive).

4. Simulation results

To study the robustness of the endogenous growth model and to compare its predictions with the exogenous growth version, we simulate four large policy changes. We assume that the economy lies on a balanced growth path at $t = 0$ that the changes are unanticipated, take place at time $t = 1$ and are permanent. Our figures represent the effect on annual output growth, annual

[6] The explosive behavior is put forward by a simple numerical procedure relying on the initialization of the relaxation. Initializing the relaxation with values slightly different from the steady state leads to an explosive behavior at the first Newton–Raphson improvement.

interest rate and income taxes in terms of deviations from the initial balanced growth path.

4.1. Debt repayment

The first policy change is a repayment of the national debt. We suppose that the debt is entirely repaid at $t = 1$, i.e., taxes are increasing during 10 years in order to fulfill this objective. Results are presented in Fig. 3.

The first effect of debt repayment is to rise the tax on labor by 9.5% in all simulations. After this initial period, the tax is lowered by 12% as there is no longer any interest payments to finance. Thus the tax rate is permanently lowered by 2.5% compared to the baseline simulation. This change in the tax profile should make investment in human capital at $t = 1$ highly profitable. Indeed, the opportunity cost is lowered by the current high tax and the expected returns are higher. Hence, the current young generation invest much more in human capital. This depresses growth in the first period as the labor force is smaller. However, future growth is enhanced. The stronger effect is obtained with scenario 3 where the elasticity of e_t to income is higher. As far as the interest rate is concerned, the long-run effect is negative as public debt no longer diverts saving from productive capital. The effects take time however since human capital accumulation is strong in periods 2–7, which initially depresses saving.

Comparing now the different scenarios, we conclude that the distinction exogenous/endogenous growth is irrelevant as far as taxes and interest rates are concerned. The major difference between the two approaches lies in the short-run effect on growth. With endogenous growth, there is an initial loss in period 1 followed by an improvement. With exogenous growth there is only a slight improvement in periods 2–7. Although the improvement in endogenous growth does not seem quantitatively important, the cumulated effect on output levels is not negligible.

4.2. Pension reform

We suppose that pay-as-you-go pensions are suppressed at $t = 1$, so that agents only rely on private savings to support their old age consumption. This simulation models a crude transition from a pay-as-you-go pension system to a fully funded private system. Results are presented in Fig. 4.

In this simulation the three endogenous growth scenarios and the exogenous growth model deliver the same conclusions. Taxes are substantially reduced (from 29% to 21%) and saving increases, which leads to a drop in the interest rate. As a consequence of these two facts, investment in education is made more attractive. Growth is boosted in period 2 thanks to the accumulation of physical capital (which takes place in the four versions of the model). In the

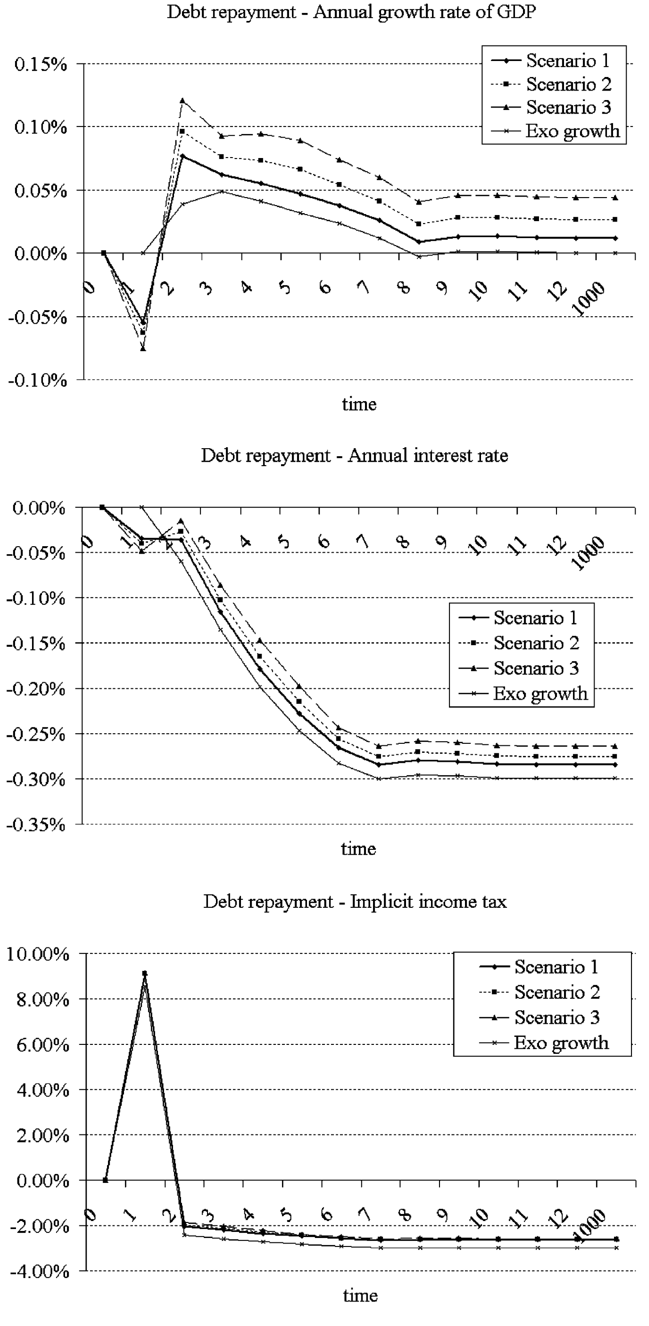

Fig. 3. Debt repayment.

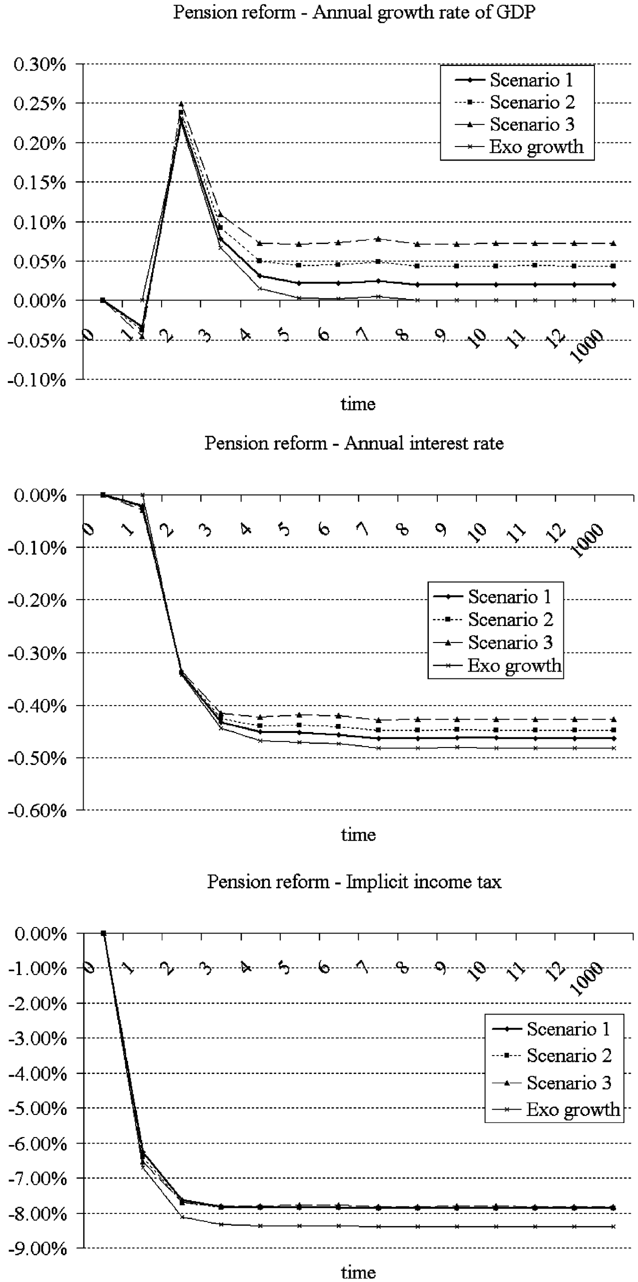

Fig. 4. Pension reform.

long-run, however, a sustained increase in the growth rate is only possible in the endogenous growth regime.

4.3. Postponing retirement

We assume that the policy parameter α goes from 0.2 to 0, which amounts to set the retirement age to 68 instead of 65. Results are presented in Fig. 5.

Once again, this policy allows to reduce the taxation rate on income by 2.5% as there is less pensions to support. As agents retire later, they need less saving to finance their old days, and the interest rate rises. The short-run rise in growth is due to the increase in the participation rate of old workers. In this simulation, the type of calibration and the presence of endogenous growth or not does not matter.

4.4. Education reform

We assume that the subsidies to education are set to zero, implying that agents have to bear 100% of their education cost. Results are presented in Fig. 6.

The direct effect of this policy is to reduce the optimal share of time devoted to education, except in the exogenous growth scenario where this share remains constant. This has a beneficial effect on growth in the short run, due to the increased activity rate of young workers. However, the lower accumulation of human capital hampers growth in the long run.

The difference between the endogenous and exogenous growth is mostly reflected in the interest rate. With exogenous growth, the drop in subsidies induces an additional cost for young households (subsidies act as lump-sum transfers since they do not affect the exogenous human capital investment), and depresses their saving. This in turn increases the rate of interest. With endogenous growth, agents adjust their time devoted to education, and the human capital accumulation is reduced. This increases the ratio of physical capital to human capital, which depresses the marginal productivity of capital and hence the interest rate.

5. Conclusion

Our purpose was to develop a larger computable model with a complete description of the public finance aggregates and to compare configurations with endogenous growth and exogenous growth specifications. Endogenous growth arises in the model thanks to the accumulation of human capital through education.

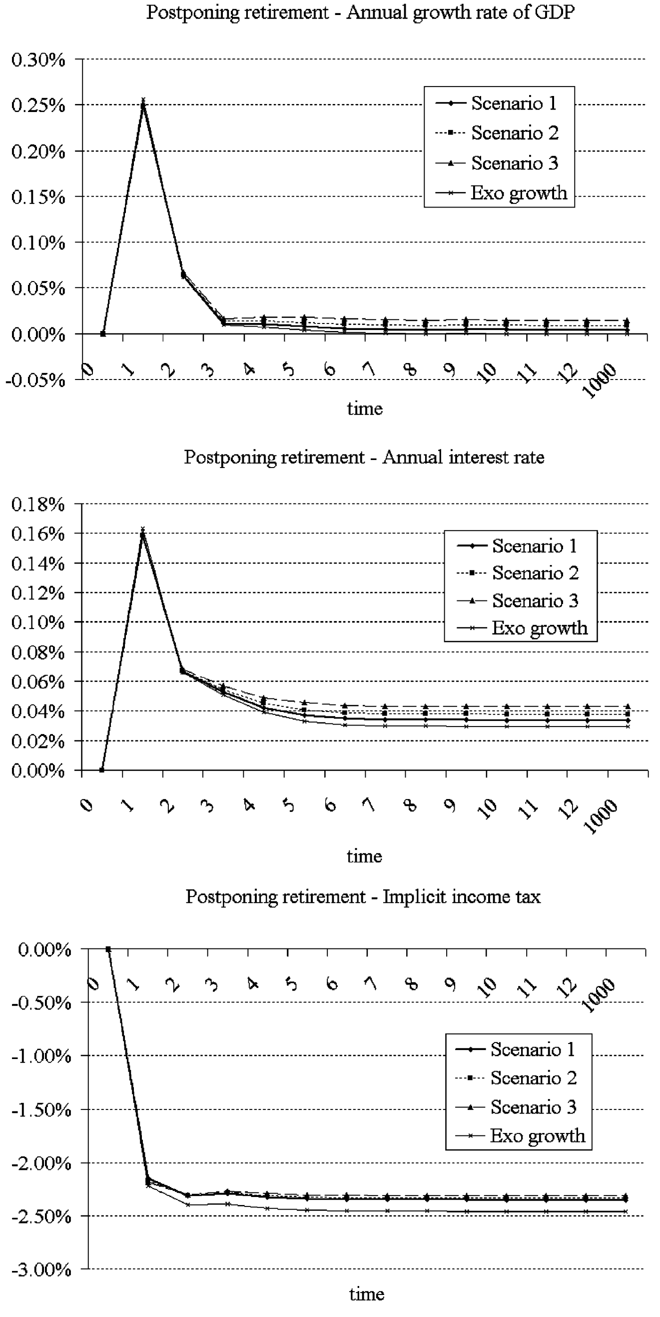

Fig. 5. Postponing retirement.

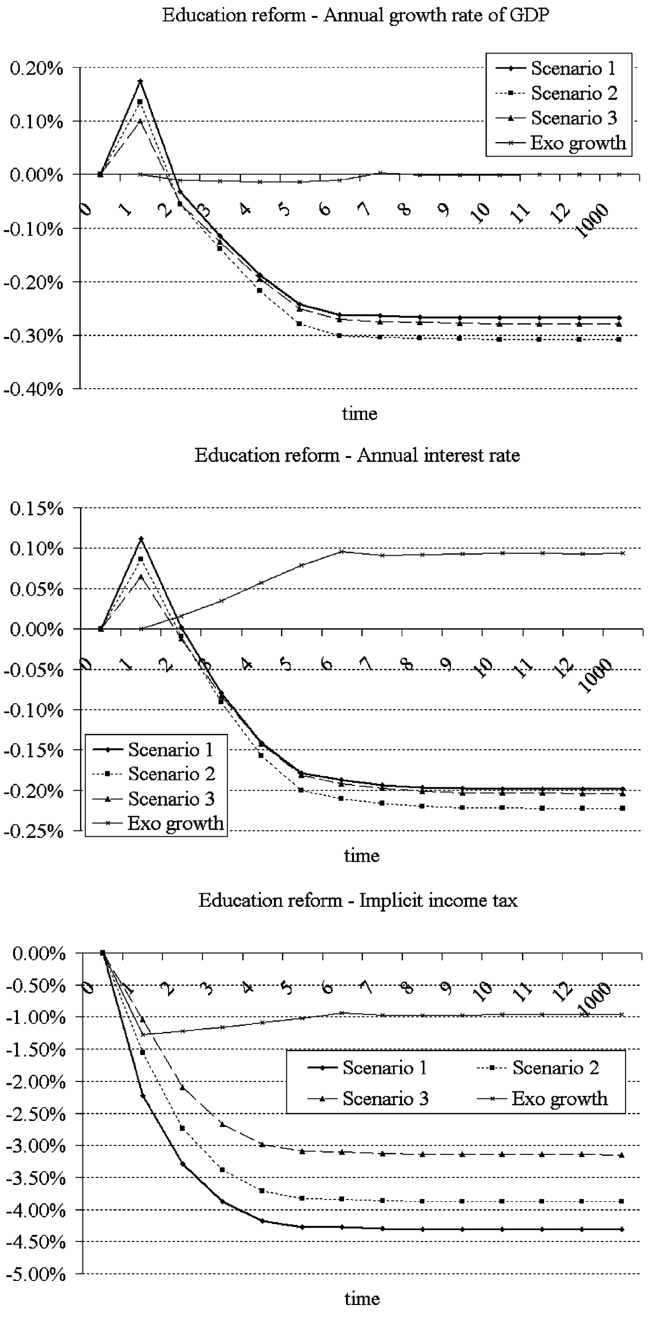

Fig. 6. Education reform.

Since we know little on the shape of the production function in the education sector, our first goal was to study the robustness of the simulation results to various calibrations of the production function of human capital. We have thus computed the response of three different calibrations of the model to four large shocks: a repayment of the whole national debt in 10 years, a switch to a fully funded pension scheme, an increase of the retirement age to 68, and an abolition of the subsidies to education. The results are encouraging: our three calibrations give reasonable results. Of course, the effect on the long-run growth rate is more important when the demand for education is more elastic to future wages.

The second question was to analyze whether endogenous growth plays a significant role in the face of external shocks? The answer is mitigated. In the two pension reform scenarios, endogenous growth does not really matter. In the debt repayment scenario, endogenous growth is particularly important for the dynamics of the growth rate. Indeed, the very high taxes in the first period and the low taxes thereafter stimulate education significantly. Finally, in the education reform scenario, endogenous and exogenous growth give opposite results in terms of growth rate and interest rate.

In a computable general equilibrium setting with realistic features and a robust parameter set, our result confirms Hendricks' interpretation about the growth effects of policy reforms. Due to the tax deductibility of human capital investments, policy reforms which do not directly affect the incentive to acquire human capital lead to small growth effects. Growth responses are only important when policy changes concern the subsidies on education. Exogenous growth may be seen as a reasonable assumption in most cases.

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