Human Capital Accumulation, Policy and Growth

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Abstract

This paper examines the general equilibrium implications of the Decentralized Education (DE) and Centralized Public Education (CPE) systems for growth and welfare in an overlapping generations growth model, where the economy-wide human capital stock generates positive externalities for each individual. Under DE, each individual agent chooses his/her human capital to maximize his/her utility function by treating the economy-wide human capital as a public good. Under CPE the economy-wide human capital can be augmented by government intervention in the form of public expenditures on education financed by distortionary income taxes. A benevolent fiscal authority chooses a uniform tax rate, and the associated expenditure on public education subject to the competitive decentralized equilibrium. It is shown that Centralized Public Education is welfare superior to decentralized education for all values of the preference parameter over total human capital bequests and initial human capital. Furthermore, CPE dominates DE for all but very high values of total human capital externalities. So, even when we abstract from equity considerations, Centralized Public Education may be supported on welfare grounds.

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1 Introduction

In Europe, North America and elsewhere, there is currently a strong debate on alternative ways of financing activities that have public good features and involve positive externalities, since competitive equilibria are typically inefficient in such cases. Education is clearly one of them, since individual human capital accumulation plays a crucial role in the process of economy-wide economic growth and income distribution in modern economies (see e.g. Lucas, 1988, Barro et al, 1995, Mundle, 1998; Temple 1999; Ranis et al., 2000, Gylfason at al, 2003, Doppelhofer et al. 2004) and we have seen significant government intervention in the funding and provision of education worldwide (e.g Gradstein et al., 2000, Thum et al., 2003). In most countries, primary and secondary education are mandatory and provided by the government and higher education is heavily subsidized (e.g by deducting educational spending from taxable income).

Education can be viewed as a mechanism of intergenerational transfers[1] , since it usually takes place at the beginning of the life cycle of the individuals and is financed by resources provided by the old generation. These transfers are altruistically motivated, but affect economic growth, income distribution and welfare through their impact on human capital accumulation (see e.g. Azariadis et al., 1990, Barro 2001, De la Croix et al., 2002). Altruistic decisions lead generally to inefficient outcomes and parental decisions about offspring education, which ignore the positive impact of individual human capital accumulation on the aggregate production, are a classic example of such decisions.

This paper compares the general equilibrium implications of two different education systems, called Decentralized Education (DE) and Centralized Public Education (CPE). This extends the work of Glomm et al. (1992) and Cardak (1999)

[1] Roughly 5% of GDP is transferred to the young generation through public education in the OECD countries (see Thum et al., 2003).

who focus on private education and CPE without human capital externalities.[2]

Under both DE and CPE, the economy-wide human capital stock generates positive externalities for each individual. That is, the return to individual education increases with economy-wide human capital. Specifically, under Decentralized Education (DE), each individual agent chooses his human capital to maximize his own utility function by treating the economy-wide human capital as a public good.

Under Centralized Public Education there is active social education policy. In particular, the economy-wide human capital is not simply the sum of individual human capital stocks, but it can be also augmented by government intervention in the form of public expenditures on education. These expenditures are financed by distortionary income taxes. Under CPE, a benevolent fiscal authority chooses a uniform tax rate, and the associated social expenditure on public education, by maximizing the utility of the representative old agent and internalizing externalities.[3]

We use an overlapping generations model based on Glomm et al. (1992), one of the most popular papers of the literature. Regarding welfare, members of the old generation have a bequest motive[4] and value total human capital transfers to the next generation as well as consumption and leisure (Zilcha, 2003). For

[2] See also Zhang (1996), Kaganovich et al. (1999), Epple et al., (1998).

[3] In a more general framework, government intervention could take various forms, such as public provision of education, provision of means-tested or uniform education vouchers to households to finance private education and deduction of educational spending from taxable income. Means-tested vouchers are transfers, which decline as the income of the recipient increases, while uniform vouchers imply that these transfers are independent of income. Also, the government can deduct the spending of households on education from income subject to taxation with the purpose of encouraging educational spending. In the context of a more detailed analysis of public centralized education than the one presented here, the effects of the above alternative education policies on growth, welfare, the level and distribution of income and educational expenditures can differ substantially (see Zhang, 1996; Kaganovich et al., 1999; Bearse et al., 2000).

[4] Generally, reasons for bequests are altruism on behalf of the parents, provision of inventives such that their heirs behave according to what parents believe is appropriate and accidental death of retired individuals who are not able to buy actuarially fair annuities. Besides that, in the absence of a bequest motive it would be difficult to explain why even very wealthy individuals maintain large asset balances at death (Azariadis, 1993).

simplicity, we focus on symmetric equilibria, where agents are alike with respect to initial human capital, preferences over leisure and over total human capital. Human capital accumulation is the engine of long-run growth and depends on initial total human capital, initial individual human capital and time devoted to education.

We characterize human capital decisions and optimal economic policy, and compare the two education systems on the grounds of endogenous variables and welfare. When we try to compare the two systems, the results are in general ambiguous depending on parameter values. Therefore, we derive analytical results where possible, and conduct numerical simulations based on well-accepted parameter values (borrowed from the empirical literature) to obtain a ranking of the education systems.

A main result is that centralized public education (CPE) is welfare superior to decentralized education (DE) for all values of the preference parameter over total human capital bequests and the welfare differential is increasing in this parameter. Furthermore, CPE outperforms DE for all but very high values of the total human capital externalities. Also, CPE is welfare preferred to DE for all values of initial human capital. Total human capital is higher under CPE compared to DE for all parameter values. Consumption is higher under DE relative to CPE. Leisure is identical under CPE and DE.

This paper is related to three strands of literature. First, it complements the literature on endogenous growth and investment in human capital (see e.g. Romer 1986, Lucas 1988, Azariadis et al., 1990). Second, it is related to research, which tries to explain the widespread public provision and financing of education as a way to indoctrinate and instill social norms and values e.g by reducing the rent-seeking incentives between competitive groups of heterogeneous agents (Gradstein 2000, Gradstein et al., 2000, 2002, Thum et al, 2003). Third, this work is relevant

to the large and diverse literature on alternative ways of financing education (see for example Glomm et al., 1992, Zhang 1996, Epple et al., 1998, Kaganovich et al., 1999, Glomm et al., 1999, Meier, 2000, Soares, 2003).

However, this paper studies two environments, the first where only private education expenditures exist and the second where both private and public education spending take place, while other authors (e.g Glomm et al., 1992, Zhang, 1996, Cardak, 1999, De la Croix et al., 2004) analyze the private and public education regimes separately. As a result, we can compare an education system where there are market failures due to externalities of total human capital in individual human capital accumulation with a regime where there are also government failures because distortionary taxes are used to finance human capital accumulation. Furthermore, we use a richer human capital accumulation specification than other studies (e.g Cardak, 1999, Preston, 2003) including time devoted to education, private education expenditures, public education spending (the latter in centralized public education) and parental human capital. We also include private human capital transfers directly in the utility function and assume that agents put different weight to the components of utility, in contrast with most of the literature (e.g Glomm et al., 1992, Zhang 1996, Cardak, 1999). Finally, we endogenize the tax rate, that is sometimes taken as exogenous (see e.g Kaganovich et al., 1999).

The rest of the paper proceeds as follows. Section 2 presents the model. Section 3 studies decentralized education. Section 4 analyzes the decentralized competitive equilibrium in the case of publicly provided education under centralized decision making. Section 5 examines optimal economic policy. Section 6 studies the dynamics of the two education systems. Section 7 compares the education systems in terms of endogenous variables and welfare. Section 8 concludes the paper. Techninal points are contained in the Appendices.

2 Theoretical framework

The analysis will be pursued in the context of an overlapping generations economy, comprised of N two-period-lived agents. Each generation consists of identical individuals, so it is characterized by a representative agent. In the second period of life each individual has one child, so population growth is zero and population is normalized to unity.[5]

Agents derive utility from leisure when young and consumption and human capital passed on to their offspring when old. This formulation is popular in the literature (see Glomm et al, 1992, Zhang, 1996, Cardak, 1999, Kaganovich et al., 1999). One unit of time is available for each agent in every period. During the first period, time is divisible in leisure and human capital investment, while in the second period all time is supplied in the labour market.

Parents and children are connected through two channels. First, the stock of parental human capital affects children's learning, since a young individual inherits partially the human capital of the parents, i.e there is intergenerational transmission of ability and knoweledge within the family that does not operate through formal schooling. Parental human capital might also affect children's human capital through the quality of parental tutoring. The second linkage between generations exists via bequests; in our model the bequest is human capital, since parents value the economy-wide human capital bequeathed to their children. This reflects education-inclined altruism of the parents and is referred in the literature as "joy of giving" (or "warm glove"), because parents have a preference for giving (Wigger, 2001, De la Croix at al., 2002).

Furthermore, the economy-wide human capital generates a positive externality in the accumulation of private human capital, i.e. it acts as an input to private

[5] For an examination of the impact of variable population growth on economic growth see e.g. Futagami et al., 2001.

human capital investment thus complementing the time devoted to education by each individual and its initial human capital. Individual agents take total human capital as given. This externality can be rationalized in several ways. For example, it has been argued that education contributes to a stable and democratic society, inculcates acceptable social values and behavioural norms, lowers crime, thus law enforcement costs and promotes social cohesion. Empirical support for these arguments has been found in the classroom and district levels (Glomm et al., 1999).

3 Decentralized Education

Under decentralized education, each agent optimizes with respect to c_{t+1} and n_t by taking aggregate human capital in all periods as given. So, he maximizes the utility function:

$$a \ln (n_t) + \ln (c_{t+1}) + b \ln (H_{t+1}) \tag{1}$$

subject to

$$h_{t+1} = c_{t+1} \tag{2}$$

$$h_{t+1} = A (1 - n_t)^{\beta} H_t^{\gamma} h_t^{\delta} \tag{3}$$

where $n_t \in [0, 1]$ is leisure in period t, c_{t+1}, h_{t+1} are consumption and individual human capital respectively in period $t+1$ and h_t is predetermined and stands for human capital in period t.[6] The last element of the utility function reflects the

[6] Regarding human capital accumulation, empirical studies show that the quality of education, measured e.g by the student/teacher ratio, term length or relative pay of teachers, influences positively the rate of return of individuals to education, therefore their future income (see Card et al., 1992). Also, the empirical work shows a positive correlation between parental

ad hoc altruism, i.e "joy of giving". The utility from leaving a bequest depends on the size of the bequest. So, b is the altruism factor reflecting the degree of parental altruism towards children expressed via human capital transfers to the offspring. Parameters a, b reflect preference for leisure and total human capital. These parameters are assumed constant over time, i.e. all generations of each family give the same weight in n_t and H_{t+1}. The differences with Glomm et al. (1992) and Cardak (1999) are that $a = b = 1$ in the former paper and $a = 1$ in the latter.

Furthermore, given the assumption that agents supply one unit of labour inelastically in the second period, h_{t+1} stands for income and the wage rate. Equation (2) is the budget constraint of the representative family, showing that disposable income is devoted entirely to consumption. Relation (3) represents a Cobb-Douglas production function for human capital, where $A > 0$ is a technological parameter that stands for total factor productivity in the human capital formation technology and $\beta, \gamma, \delta \in (0, 1)$ exhibit the elacticities of the learning process with regard to time devoted to education, initial total human capital and inherited individual human capital respectively, so that all factors exhibit diminishing returns. It shows that human capital accumulation depends positively on time devoted to schooling, $(1 - n_t)$, economy-wide human capital H_t and human capital provided by the parents h_t. So, the more educated parents are, the more help they are likely to give to their offspring and the more educated the latter are likely to be.

In the context of all education systems examined below, we assume that agents

knowledge and child performance in school (see Glomm et al., 1992), parental schooling and children‘s schooling (e.g Plug, 2004), parental income and children's income (De la Croix et al., 2002), parents‘ income and human capital investments (see Grossmann, 2003). In our paper human capital is the only source of income, therefore modelling human capital investment as a function of parents‘ human capital seems reasonable. Furthermore, time spent on human capital investment is expected to have a positive effect on school performance.

are alike.[7]

The first-order conditions define the equilibrium as follows:[8]

$$n_t^{DE} = \frac{a}{a+\beta} \tag{4}$$

$$h_{t+1}^{DE} = c_{t+1}^{DE} = A\left(\frac{\beta}{a+\beta}\right)^{\beta} H_t^{\gamma} h_t^{\delta} = AN^{\gamma}\left(\frac{\beta}{a+\beta}\right)^{\beta} h_t^{\gamma+\delta} = G_{DE}(a)\, h_t^{\gamma+\delta} \tag{5}$$

$$H_{t+1}^{DE} = Nh_{t+1}^{DE} = NA\left(\frac{\beta}{a+\beta}\right)^{\beta} H_t^{\gamma} h_t^{\delta} = AN^{1+\gamma}\left(\frac{\beta}{a+\beta}\right)^{\beta} h_t^{\gamma+\delta} \tag{6}$$

Equation (4) indicates that labour/leisure choices are constant over time and independent of the parental attributes h_t, because the income and substitution effects balance each other perfectly.[9] The equilibrium labour supply is conditional on a, β. The stronger the preference over leisure α and the smaller the elasticity of human capital accumulation with regard to time devoted to it β, the higher is optimal leisure. Also, consumption, income and total human capital in period $t+1$ depend positively on the elasticity of human capital accumulation with regard to time allocated to it β. Furthermore, they are positive functions of the productivity parameter A, the elasticity of future human capital with respect to initial human capital $(\gamma+\delta)$ and initial human capital h_t. Finally, income, consumption and aggregate human capital depend negatively on the preference over leisure. Furthermore, total human capital is a positive function of the number of private agents.

[7] The solution concept of symmetric equilibria has been widely used by both the public economics and the game-theoretic literature (see Bewley, 1982, Mueller 1989, Drazen 2000, Persson et al. (1992,1994), Philippopoulos et al., 2003).

[8] The second-order conditions hold. The superscript DE stands for Decentralized Education equilibrium.

[9] This is due to log-linear preferences.

Regarding growth, which is the focus of this paper, $G_{DE}(a)$ stands for the growth rate of income under DE (see equation (5)). By partial differentiation with regard to $a, A, \beta, \gamma, \delta, N$ we have:

Proposition 1 *In a decentralized education system, economic growth depends negatively on the preference over leisure α and positively on total factor productivity A and the elasticity of future human capital with regard to time devoted to education β. Also, individual income and consumption increase with the magnitude of the total human capital externality γ, the elasticity of future human capital with regard to initial human capital δ and the number of agents N. Finally, total human capital is a positive function of the total human capital externality γ.*

The latter holds because there are aggregate human capital externalities in the production of individual human capital in the context of DE.

4 Centralized public education

We now assume that the economy-wide human capital stock is not simply the sum of the human capital stocks of individual agents but can be also augmented by the government in the form of public expenditures on education (e.g public programs for libraries,expenditures on building schools, teachers' and university professors' salaries and training). These expenditures are financed by distortionary taxes on agents' initial human capital. A possible interpretation of the simultaneous presence of private and public human capital expenditures in the production of human capital is that the majority of public education spending finances primary and secondary education, while private expenditure finances mainly tertiary education and on the job-training (Blankenau et al., 2004).

Events take place in two stages. First, a centralized fiscal authority chooses the tax rate and the associated level of government expenditures This choice is made either by a central planner (centralized equilibrium), taking as given the equilibrium values of consumption and leisure chosen by households (see also e.g.

Alesina et al., 1994). Second, agents choose consumption, human capital and leisure (therefore time devoted to education) taking economic policy as given.

4.1 Household behaviour

Solving the problem backwards, in the second stage, the representative agent born in period t chooses c_{t+1}, n_t taking total human capital and the income tax rate as given to maximize lifetime utility as follows:

$$a \ln (n_t) + \ln (c_{t+1}) + b \ln (H_{t+1}) \tag{7}$$

subject to

$$\begin{aligned} h_{t+1} &= c_{t+1} && (8) \\ h_{t+1} &= A (1 - n_t)^{\beta} H_t^{\gamma} (1 - \tau_{t+1})^{\delta} h_t^{\delta} && (9) \end{aligned}$$

Equation (8) states that consumption equals the net (after-tax) human capital. Relation (9) represents the human capital production function and compared to (3), it includes a proportional tax on initial individual human capital. It also incorporates aggregate human capital in period t as an externality for all agents similarly with the DE system.

In the Glomm at el. (1992) and Cardak (1999) papers, education quality intstead of total human capital is used in the utility and production functions and education quality is financed exclusively by a proportional tax on period $t + 1$ income.

Relation (10) stands for the government budget constraint. Relation (11) represents the fact that total human capital in period $t + 1$ is the sum of private

agents' human capital stocks and the government education expenditures financed by a proportional tax τ_{t+1} on period t income. In the Glomm at al (1992) and Cardak (1999) papers, education quality instead of total human capital is used in the utility and production functions and education quality is financed exclusively by a proportional tax on period $t+1$ income.

Equations (8)-(9) imply that

$$c_{t+1} = A\left(1-n_t\right)^{\beta} H_t^{\gamma}\left(1-\tau_{t+1}\right)^{\delta} h_t^{\delta} \tag{10}$$

The first-order conditions imply:

$$c_{t+1} = \frac{A\beta}{a} n_t \left(1-n_t\right)^{\beta-1} H_t^{\gamma}\left(1-\tau_{t+1}\right)^{\delta} h_t^{\delta} \tag{11}$$

from which we get after using (10) and some algebra[10]

$$n_t^{CPE} = \frac{a}{a+\beta} \tag{12}$$

$$h_{t+1}^{CPE} = c_{t+1}^{CPE} \tag{13}$$

$$h_{t+1}^{CPE} = A\left(\frac{\beta}{a+\beta}\right)^{\beta} H_t^{\gamma}\left(1-\tau_{t+1}\right)^{\delta} h_t^{\delta} = AN^{\gamma}\left(\frac{\beta}{a+\beta}\right)^{\beta}\left(1-\tau_{t+1}\right)^{\delta} h_t^{\gamma+\delta} \tag{14}$$

The above results are similar to those in Glomm at al. (1992) and Cardak (1999) and analogous to those obtained under decentralized education. The differences between decentralized education and centralized public education are as follows:

Proposition 2 *Individual consumption and human capital are lower in centralized public education than in decentralized education due to the imposition of the tax on human capital. Total human capital in period t+1 is augmented by government expenditures on education in CPE, which are not present under DE.*

[10] The second-order conditions are also satisfied.

4.2 Government budget constraint

The government runs a balanced budget. It uses revenues from proportional taxation of initial human capital and allocates them to spending on economy-wide human capital (G).

Given that there are N private agents, the government budget constraint is:

$$G = \tau_{t+1} N h_t = \tau_{t+1} H_t \tag{15}$$

Equation (15) implies that economic policy is summarized by the tax rate on initial human capital (τ_{t+1}).

4.3 Competitive decentralized equilibrium

Given the policy instrument τ_{t+1}, the Competitive Decentralized Equilibrium (CDE) is defined as the set of allocations $(n_t, c_{t+1}, h_{t+1}, \tau_{t+1})$ such that: (i) households maximize utility given economic policy; (ii) markets clear; (iii) the government budget constraint is satisfied. We will make use of the specific functional forms and try to obtain closed-form solutions for the elements of the CDE.

Taking into account our theoretical framework and using (12)-(15), we get the following:

Proposition 3 *In a symmetric competitive decentralized equilibrium (given any economic policy), optimal leisure, consumption, individual human capital, public spending on economy-wide human capital and total human capital are respectively:*

$$n_t^{CPE} = \frac{a}{a+\beta} \tag{16}$$

$$h_{t+1}^{CPE} = c_{t+1}^{CPE} = A\left(\frac{\beta}{a+\beta}\right)^{\beta} H_t^{\gamma}\left(1-\tau_{t+1}\right)^{\delta} h_t^{\delta} = AN^{\gamma}\left(\frac{\beta}{a+\beta}\right)^{\beta}\left(1-\tau_{t+1}\right)^{\delta} h_t^{\gamma+\delta} \tag{17}$$

$$G = \tau_{t+1} H_t \tag{18}$$

$$H_{t+1}^{CPE} = N h_{t+1} + G = A N^{1+\gamma} \left(\frac{\beta}{a+\beta} \right)^{\beta} (1 - \tau_{t+1})^{\delta} h_t^{\gamma+\delta} + \tau_{t+1} H_t \tag{19}$$

This holds for any fiscal policy, which is represented by the income tax rate τ_{t+1}. In the next section, we will endogenize the choice of τ_{t+1}.

5 Optimal Economic Policy

To endogenize economic policy, it is sufficient to determine the independent policy instrument (τ_{t+1}). So, we consider a centralized fiscal authority, that chooses the tax rate on initial human capital (τ_{t+1}) .This authority acts as a benevolent Stackelberg leader vis-a-vis the private sector by taking into account the competitive decentralized equilibrium.

As a result, the problem consists in choosing τ_{t+1}, which maximizes the utility of the representative household given in (1). Substituting (15)-(19) into (1) and differentiating with respect to τ_{t+1} the first-order condition is the following:[11]

$$-\delta A \left(\frac{\beta}{a+\beta} \right)^{\beta} H_t^{\gamma} (1 - \tau_{t+1})^{\delta} h_t^{\delta} + b h_t = (b + \delta) h_t \tau_{t+1} \tag{20}$$

A closed-form solution for τ_{t+1} can not be found from equation (20), so we will check if an equilibrium tax rate exists and if it is unique. We denote the right-hand side of (20) by RHS and the left-hand side by LHS and take the first and second derivatives of RHS and LHS with respect to τ_{t+1}. We conclude that the RHS is a straight line and the LHS is increasing and convex with regard to τ_{t+1} . Also, the RHS starts from the origin and the LHS starts above the origin and below bh_t . As a result, RHS and LHS cross at one point for $\tau_{t+1} \in (0, 1)$ (see Appendix A and Figure 5). The following conclusion emerges:

[11] The second-order conditions of the problem are outlined in Appendix A.

Proposition 4 *Under centralized public education, a unique equilibrium tax rate exists.*

The tax rate depends on the strength of preferences of the private agents over leisure (a) and total human capital bequests (b), the elacticities of future human capital with regard to i) time allocated to learning (β), ii) total human capital which provides economy-wide externalities to individual human capital accumulation (γ) iii) after-tax initial individual human capital (δ). Also, the optimal tax is a function of total factor productivity in the human capital accumulation process (A), initial individual human capital (h_t) and the number of private agents (N). In order to solve for τ_{t+1}, we resort to numerical methods by using Mathematica Version 4. The baseline values substituted in for the parameters of the model are $a = 0.17, b = 0.5, \beta = 0.3, \gamma = 0.15, \delta = 0.35, A = 1, h_t = 100, N = 10^5$. The values for β, γ, δ were obtained from a similar analysis in Benhabib et al. (1994), Psaharopoulos(1985), Card et al. (1996), Magoula et al. (1997) and Acemoglou et al. (1999). The a, b were chosen so that the agents put more weight on consumption, education and leisure sequentially and A, h_t, N were set arbitrarily for reasons of simplicity.

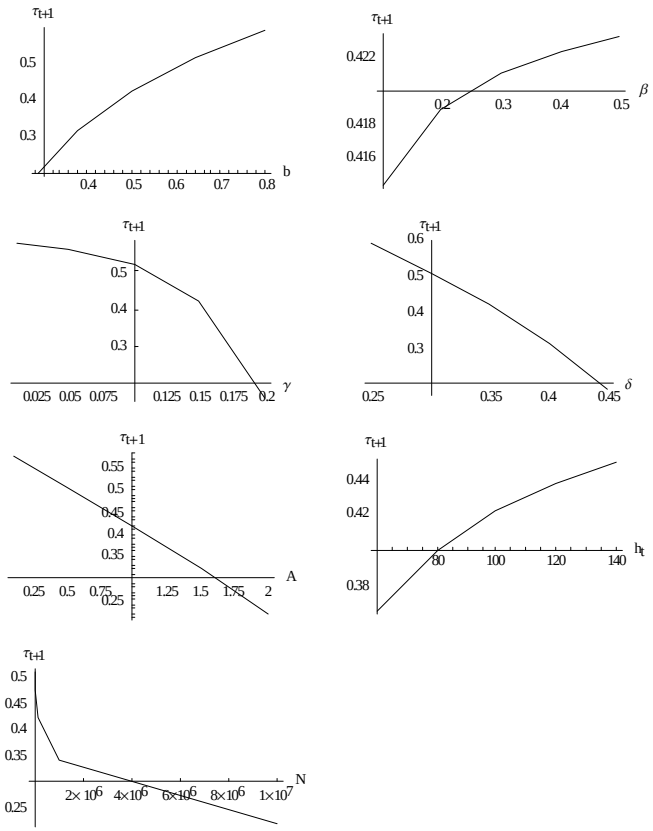
The tax rate is found to be equal to $\tau_{t+1} = 0.421$, therefore there is a unique equilibrium tax rate on initial human capital equal to approximately 42.1%.[12]

A sensitivity analysis of the tax rate with regard to the model's parameters $b, \beta, \gamma, \delta, A, h_t, N$ is conducted and presented in Figure 1 (Tables B1-B7 in Appendix B correspond to Figure 1). The range of values is such that $b \in [0.29, 0.8]$, $\beta \in [0.1, 0.5], \gamma \in [0.01, 0.2], \delta \in [0.25, 0.45]$, $A \in [0.1, 2], h_t \in [60, 140], N \in [10^3, 10^7]$. These ranges are broad enough to include any empirically plausible values of the parameters.

From the figure it follows that the optimal tax rate is increasing in the pref-

[12] The second-order condition of the problem holds for the baseline parameter values.

Figure 1: Sensitivity of τ_{t+1} wrt $(b, \beta, \gamma, \delta, A, h_t, N)$



erence parameter over total human capital (b). This is intuitively appealing, as the stronger the preference of the agents for total human capital, the more money they will be willing to pay for the subsidization of human capital accumulation and this is reflected in a higher optimal tax rate.

The tax increases with the elasticity of future human capital with regard to time devoted to education (β). This is reasonable because a higher tax rate yields larger revenue and the accompanying distortions are compensated by the higher productivity of learning time.

Furthermore, the tax rate is decreasing in the production externality of total human capital (γ). This results from the fact that the larger this externality, the higher the potential of income generation for a given tax rate, the larger the tax base and the smaller the tax rate necessary to finance a given amount of total human capital.

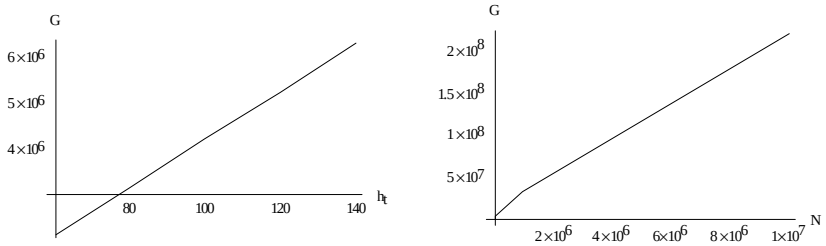
Also, the stronger the dependence of future human capital on initial human capital (δ), the lower the optimal tax rate. The growth-depressing effect of any given tax rate becomes more severe with higher δ, so there is scope for lower taxation.

Besides that, the higher total factor productivity A, the lower tax is necessary to raise the revenues required for the subsidization of human capital accumulation, so the lower the optimal tax rate.

We see that the higher the initial individual human capital (h_t), the higher the optimal tax rate. This outcome reflects the greater revenue generation potential of taxation, which compensates for the distortionary effect of taxation in the process of raising funds for financing public education expenditures.

Additionally, the larger the number of private agents in the economy (N), the higher the initial total human capital and the lower the tax required to finance any given level of education spending.

Figure 2: Sensitivity of G wrt (h_t, N)



Finally, government spending changes in the same direction with τ_{t+1}, when parameter values vary, since it is equal to $\tau_{t+1} N h_t$, with the possible exception of the relation with h_t, N, which affect both τ_{t+1} and G directly (see Figure 2 and Tables B1-B7 in Appendix B). So, spending on education increases when agents have stronger preferences over total human capital bequests (b) and human capital accumulation is more elastic with respect to learning time and initial individual human capital $(\beta, h_t$ respectively). On the contrary, public education expenditure falls with the degree of sensitivity of human capital accumulation with respect to initial total and individual human capital $(\gamma, \delta$ respectively), total factor productivity (A) and the number of agents (N).

6 Dynamics

In this section we study the dynamic path of human capital under the two education regimes, namely DE and CPE.

In the context of decentralized education, we derive the dynamics of private human capital by examining equation (5).

i) If $(\gamma + \delta) \in (0, 1)$, the economy converges monotonically to the steady-state level of human capital. The latter is given by $h_s^{DE} = [G_{DE}(a)]^{\frac{1}{1-\gamma-\delta}}$

ii) If $\gamma + \delta = 1$, the human capital of every family exhibits long-run or endogenous growth at a rate of $G_{DE}(a)$. One can distinguish three subcases:

a) $G_{DE}(a) = 1$. We get $h_{t+1} = h_t$, therefore the respresentative agent stays at the human capital given by his initial conditions and there is no unique steady-state.

b) $G_{DE}(a) < 1$. There is monotonic convergence to a steady-state human capital equal to zero.

c) $G_{DE}(a) > 1$. All families experience long-run growth, which is higher, the lower α is.

iii) If $\gamma + \delta > 1$, the representative family converges to one of two steady-state levels of human capital, equal to 0 and $[G_{DE}(a)]^{\frac{1}{1-\gamma-\delta}}$, depending on initial conditions, i.e. the equilibria are unstable. Specifically, if $h_1 < [G_{DE}(a)]^{\frac{1}{1-\gamma-\delta}}$, then $h_t \to 0$. If $h_1 > [G_{DE}(a)]^{\frac{1}{1-\gamma-\delta}}$, then $\lim_{t\to\infty} h_t = 0$ and if $h_1 = [G_{DE}(a)]^{\frac{1}{1-\gamma-\delta}}$ individual human capital will rest at its initial condition.

The cases of primary economic interest are i) and iic) and the conclusions may be summarized as follows:

Proposition 5 *a) If $(\gamma + \delta) \in (0, 1)$, the representative family's human capital converges monotonically to the steady-state level of human capital. The latter depends negatively on how much agents value leisure; b) If $\gamma+\delta = 1$ and $G_{DE}(a) > 1$ the agents' income exhibits long-run growth, which is higher the weaker the preference over leisure.*

Regarding the dynamics of total human capital they are the same with those of private capital, the only difference being that the level of total human capital is always higher than private human capital, since the former is the sum of the human capital of the private agents.

With regard to CPE, the dynamics are qualitatively the same compared with DE. The difference of DE with CPE is that the latter regime is affected in terms of growth by the tax rate, which does not exist under DE. The tax rate lowers the rate of private human capital accumulation, but has an ambiguous effect on total human capital accumulation due to the public investment on economy-wide

human capital.

As a conclusion, the dynamics are qualitatively similar in both regimes allowing for a variety of growth paths, including the neoclassical and endogenous growth as subcases.

7 Comparison of education systems

In what follows, we compare Decentralized Education (DE) and Centralized Public Education (CPE). The purpose of the comparison is to examine the trade-off between market failures associated with DE, due to the non-internalization of the externalities associated with total human capital, and government failures under CPE arising from the attempt by the government to correct the resulting inefficiency by using distorting policy instruments, here income taxes. These taxes create distortions, therefore inefficiencies, themselves. In order to examine the trade-off between market failures and government failures, first we compare the two systems in terms of leisure/time devoted to education, individual human capital and consumption. The results are summarized as follows:

Proposition 6 *a) Leisure, therefore time devoted to education, are identical in both decentralized education and centralized public education systems; b) Individual human capital and consumption are higher under DE than CPE.*

This outcome comes from the fact that the representative agent maximizes exactly the same utility function subject to the same constraints under the two regimes. The only difference comes from the imposition of the tax on human capital under CPE, which causes human capital and consumption to be lower in comparison with DE, due to the distortionary nature of the tax for the accumulation process. In other words, the cost of tax distortions outweighs the benefit from the internalization of human capital externalities regarding individual human

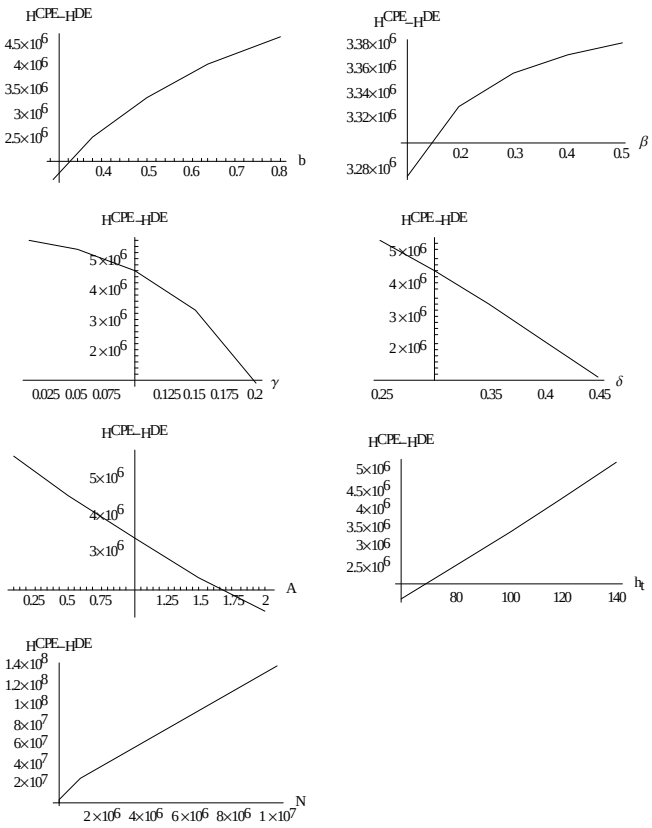
capital and consumption. This happens because taxes are levied at the individual level and human capital accumulation is subsidized at the aggregate level.

However, both education systems involve second-best environments and there is no a priori guidance from our theoretical model as to which of DE/CPE performs better in terms of total human capital and overall welfare. This is due to the subsidization of total human capital by the government in the framework of CPE although DE is superior to CPE in terms of individual human capital. This implies that the welfare comparison of these regimes for all parameter values is impossible, because total human capital is an argument of the utility function. At the same time, a welfare analysis is useful even in the context of a representative agent model as ours, since it summarizes the effects of changes in the model's parameters on utility, which the social planner aims at maximizing through the use of the various policy instruments.

As a result, we evaluate total human capital and welfare for the benchmark parameter values and then for a range of values of the model's parameters, i.e we perfom a sensitivity analysis, with regard to the model parameters $b, \beta, \gamma, \delta, A, h_t, N$ using the same range of values as before. So, $b \in [0.29, 0.8]$, $\beta \in [0.1, 0.5]$, $\gamma \in [0.01, 0.2]$, $\delta \in [0.25, 0.45]$, $A \in [0.1, 2]$, $h_t \in [60, 140]$, $N \in [10^3, 10^7]$, where recall that b is the strength of preferences over total human capital, β, γ, δ stand for the elasticities of human capital accumulation with regard to time devoted to education, total human capital and initial human capital respectively. Also, A stands for the productivity of human capital accumulation with respect to all inputs, h_t is the initial individual human capital and N is the number of agents. The above ranges are broad enough to include most empirically plausible values of the parameters.

Regarding the baseline parameter values, we get that $H_{t+1}^{DE} < H_{t+1}^{CPE}$ and $U^{DE} < U^{CPE}$. So, centralized public education is superior to decentralized edu-

Figure 3: Sensitivity of $H^{CPE} - H^{DE}$ wrt $(b, \beta, \gamma, \delta, A, h_t, N)$



cation in terms of both total human capital and welfare, i.e the subsidization of total human capital outweighs the distortions caused by the taxation of individual human capital.

The results of the sensitivity analysis for $H_{t+1}^{CPE} - H_{t+1}^{DE}$, $U^{CPE} - U^{DE}$ are presented in Figures 3-4 (Tables D1-D7 in Appendix D correspond to Figures 3-4).

Regarding the preference parameter over total human capital bequests (b), centralized public education is superior to decentralized education for all parameter values in terms of both total human capital and welfare and the differential

of the two education systems increases with b.This is to be expected, because the higher the weight the agents give to human capital, the more heavily they will invest in it, the faster human capital accumulation will be in CPE, and the higher the welfare they will get from human capital, therefore total welfare.

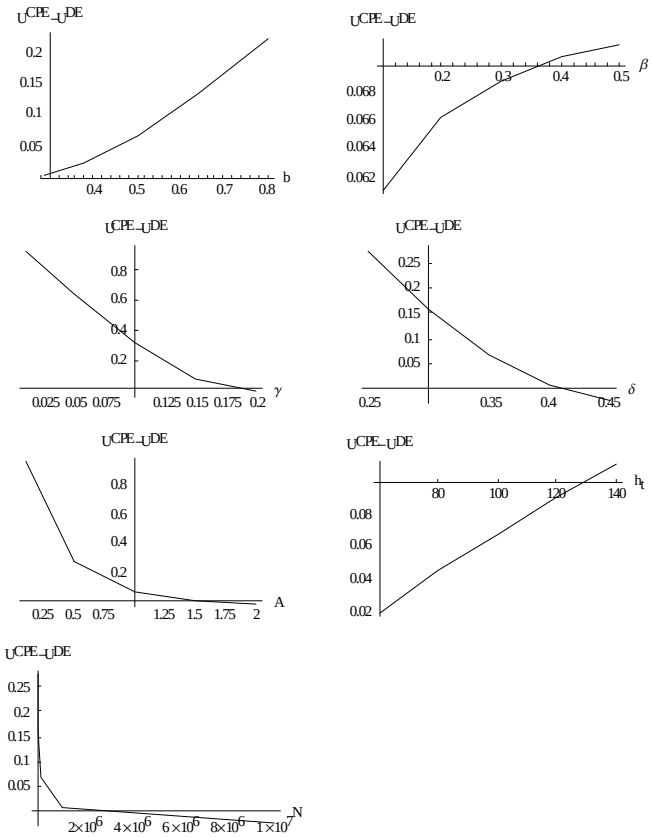
Concerning the elasticity of human capital accumulation with respect to time allocated to education (β), CPE is superior to DE for both total human capital and welfare and the differential between the systems rises with β. This is plausible, since a higher β implies higher tax rate, therefore public education spending, which outweighs the lower private human capital accumulation due to tax distortions, hence total human capital increases resulting in higher welfare under CPE compared to DE.

With respect to the sensitivity of human capital accumulation with regard to total human capital (γ), centralized public education outperforms decentralized education for all parameter values except for one case, i.e when externalities are particularly strong. As γ rises, the differential between the values of total human capital and welfare declines reflecting the fact that the tax rate, therefore public education funding, fall. That results in lower welfare differential between the two systems. These results hold exactly for the elasticity of human capital accumulation with regard to initial individual human capital (δ) and the logic behind them is the same as before.

As far as total factor productivity (A) is concerned, CPE does better than DE regarding total human capital and welfare expect for very high values of A, but the differential of the two systems for these variables declines with A. This is reasonable, since a higher A implies a lower tax rate, therefore lower government funding of education, total human capital and welfare in the context of CPE.

Furthermore, CPE fares better than DE in terms of total human capital and welfare for the whole range of values of initial individual human capital (h_t). Also,

Figure 4: Sensitivity of $U^{CPE} - U^{DE}$ wrt $(b, \beta, \gamma, \delta, A, h_t, N)$



the higher h_t is, the higher the differential of the two education systems with regard to the above variables, since the optimal tax rate is higher, which implies higher public education funding, which outweighs the lower private human capital accumulation due to higher taxes.

Finally, centralized public education outperforms decentralized education for all but the highest value of the number of agents (N). The lower optimal tax rate is outweighed by the higher number of agents implying larger tax revenues and government education funding. As a result, we have higher total human capital differential of CPE in comparison with DE. However, the welfare differential

declines gradually in favour of decentralized education as the number of agents rises.

Regarding the parameter of the degree of education-inclined altruism towards the young (b), one could speculate that its magnitude is significantly larger in the south European countries than the North Europe and North America. This is plausible because citizens in the former set of countries seem to value education per se, i.e. not only as a means of having better labour market opportunities and higher earnings, but also as a way to improve their social status or to shape a better personality. On the contrary, in the North, agents value education more as an investment. So, people in the North are less willing to pay taxes for education finance. This justifies a more important role for centralized public education in the South.

8 Conclusions

This paper has examined the implications of decentralized education and centralized public education systems for growth and welfare. We focused on education, because human capital accumulation is considered as a fundamental source of long-run growth in modern economies and government intervention in education is widespread. The ultimate objective was to welfare rank the two regimes, so that a formal judgement can be made regarding their desirability as alternative ways of organizing education.

Our study shows that definitive comparisons can be made for time devoted to education (therefore leisure), individual human capital and consumption. Time spent on education, therefore leisure, is identical in both regimes. Concerning individual capital and consumption, DE dominates CPE.

However, none of the institutional settings dominates the rest for all parameter values in terms of total human capital and welfare. In light of this, we resorted to

numerical methods. A main result is that centralized public education is welfare superior to decentralized education for all values of the preference parameter over total human capital bequests and the welfare differential is increasing in this parameter. Furthermore, CPE dominates DE for all but very high values of the total human capital externalities. Also, CPE is welfare superior to DE for all values of initial human capital. However, decentralized education is welfare superior when human capital is very elastic with regard to initial individual human capital, total factor productivity is high and the number of agents is large. So, even when we abstract from equity considerations as we do in this work, centralized public education may be supported on welfare grounds.

These results, if combined with the strong capacity of public education to reduce income inequality when asymmetric equilibria ex-post are studied, as in Glomm at al. (1992) and Cardak (1999) among others, justify a prominent role for public centralized education.

We close with possible extensions. First, we could examine an economy where the individuals in each generation are heterogeneous, allowing for more elaborate education policies, e.g means-tested vouchers, which would allow us to study the impact of education policies on income distribution. We might also assume the more realistic case, where direct government education spending is not a pure public good, but a public good subject to congestion. Furthermore, we might study the case of progressive in addition to proportional taxation of initial human capital and model uncertainty with respect to the characteristics of human capital accumulation. We leave these extensions for the future.

APPENDICES

APPENDIX A

We denote the right-hand side of equation (20) $RHS^1 = (b+\delta)\, h_t \tau_{t+1}$ (A1) and the left-hand side $LHS^1 = -\delta A \left(\frac{\beta}{a+\beta}\right)^{\beta} H_t^{\gamma} (1-\tau_{t+1})^{\delta} h_t^{\delta} + bh_t$ (A2).

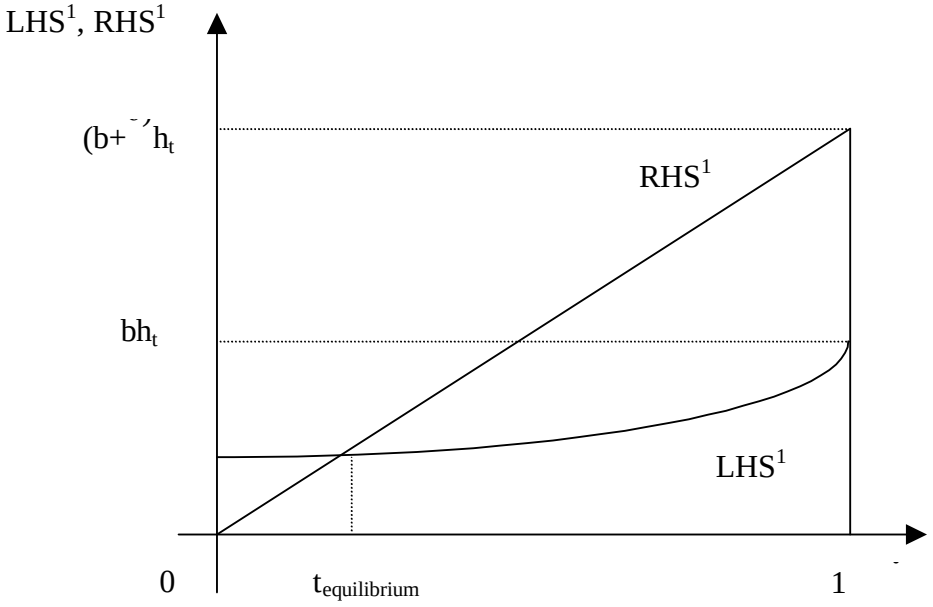
The partial derivatives of RHS^1 and LHS^1 with respect to τ_{t+1}, from now on we suppress $t+1$ from τ_{t+1} for notational simplicity, are $RHS^1_{\tau} = (b+\delta)\, h_t$ (A3) and $LHS^1_{\tau} = A\delta^2 \left(\frac{\beta}{a+\beta}\right)^{\beta} H_t^{\gamma} (1-\tau)^{\delta-1} h_t^{\delta} > 0$ (A4).

The second partial derivatives of RHS^1 and $LHS^1$with regard to τ are given by $RHS^1_{\tau\tau} = 0$ (A5) and $LHS^1_{\tau\tau} = -A\delta^2 \left(\frac{\beta}{a+\beta}\right)^{\beta} H_t^{\gamma} (\delta-1)(1-\tau)^{\delta-2} h_t^{\delta} > 0$ (A6).

Consequently, the RHS^1 is an increasing straight line and the LHS^1 is increasing and convex with respect to τ. Also, for $\tau = 0$, $RHS^1 = 0$, and for $\tau = 1$, $RHS^1 = (b+\delta)\, h_t$, so the RHS^1 starts from the origin and ends at the point $(1, (b+\delta)\, h_t)$. Furthermore, for $\tau = 0$, $0 < LHS^1 = -\delta A \left(\frac{\beta}{a+\beta}\right)^{\beta} H_t^{\gamma} h_t^{\delta} + bh_t < bh_t$ and for $\tau = 1$, $LHS^1 = bh_t$. Therefore, the LHS^1 starts above the origin and below $(0, bh_t)$ and ends at $(1, bh_t)$.

As a result, RHS^1 and LHS^1cross at a single point for $\tau \in (0,1)$, so we have a unique equilibrium tax rate (see Figure 5).

Figure 5: Existence/uniqueness of τ_{t+1}



APPENDIX B

Table B1. Sensitivity analysis of (τ_{t+1}, G) wrt b

b	τ_{t+1}	G
0.29	0.2	1.995×10^6
0.38	0.311	3.110×10^6
0.5	0.421	4.211×10^6
0.64	0.512	5.122×10^6
0.8	0.588	5.880×10^6

Table B2. Sensitivity analysis of (τ_{t+1}, G) wrt β

β	τ_{t+1}	G
0.1	0.414	4.144×10^6
0.2	0.419	4.189×10^6
0.3	0.421	4.211×10^6
0.4	0.422	4.224×10^6
0.5	0.423	4.233×10^6

Table B3. Sensitivity analysis of (τ_{t+1}, G) wrt γ

γ	τ_{t+1}	G
0.01	0.572	5.725×10^6
0.05	0.558	5.579×10^6
0.10	0.518	5.182×10^6
0.15	0.421	4.211×10^6
0.2	0.162	1.624×10^6

Table B4. Sensitivity analysis of (τ_{t+1}, G) wrt δ

δ	τ_{t+1}	G
0.25	0.591	5.911×10^6
0.3	0.511	5.110×10^6
0.35	0.421	4.211×10^6
0.4	0.315	3.146×10^6
0.45	0.182	1.825×10^6

Table B5. Sensitivity analysis of (τ_{t+1}, G) wrt A

A	τ_{t+1}	G
0.1	0.573	5.732×10^6
0.5	0.509	5.094×10^6
1	0.421	4.211×10^6
1.5	0.323	3.235×10^6
2	0.217	2.166×10^6

Table B6. Sensitivity analysis of (τ_{t+1}, G) wrt h_t

h_t	τ_{t+1}	G
60	0.365	2.193×10^6
80	0.399	3.191×10^6
100	0.421	4.211×10^6
120	0.437	5.246×10^6
140	0.449	6.292×10^6

Table B7. Sensitivity analysis of (τ_{t+1}, G) wrt N

N	τ_{t+1}	G
10^3	0.509	50917.1
10^4	0.474	473800
10^5	0.421	4.211×10^6
10^6	0.341	3.412×10^7
10^7	0.218	2.177×10^8

APPENDIX C

Using relations (6), (19) we obtain

$$H_{t+1}^{DE} - H_{t+1}^{CPE} = N^{1+\gamma} A \left(\frac{\beta}{\alpha+\beta}\right)^{\beta} h_t^{\gamma+\delta} \left[1 - (1-\tau_{t+1})^{\delta}\right] - 2\tau_{t+1} h_t \tag{C1}$$

Also, (1), (4)-(6), (17)-(19) give

$$U^{DE} - U^{CPE} = \ln\left[\frac{1}{(1-\tau_{t+1})^{\delta}}\right] + b\ln\left[\frac{N^{\gamma}A\left(\frac{\beta}{\alpha+\beta}\right)^{\beta} h_t^{\gamma+\delta}}{N^{\gamma}A\left(\frac{\beta}{\alpha+\beta}\right)^{\beta} h_t^{\gamma+\delta}(1-\tau_{t+1})^{\delta} + \tau_{t+1} h_t}\right] \tag{C2}$$

APPENDIX D

Table D1. Sensitivity analysis of $H_{t+1}^{CPE} - H_{t+1}^{DE}, U^{CPE} - U^{DE}$ wrt b

b	$H_{t+1}^{CPE} - H_{t+1}^{DE}$	$U^{CPE} - U^{DE}$
0.29	1.62×10^6	0.003
0.38	2.501×10^6	0.024
0.5	3.355×10^6	0.069
0.64	4.037×10^6	0.134
0.8	4.593×10^6	0.225

Table D2. Sensitivity analysis of $H_{t+1}^{CPE} - H_{t+1}^{DE}, U^{CPE} - U^{DE}$ wrt β

β	$H_{t+1}^{CPE} - H_{t+1}^{DE}$	$U^{CPE} - U^{DE}$
0.1	3.274×10^6	0.061
0.2	3.329×10^6	0.066
0.3	3.355×10^6	0.069
0.4	3.371×10^6	0.070
0.5	3.381×10^6	0.072

Table D3. Sensitivity analysis of $H_{t+1}^{CPE} - H_{t+1}^{DE}, U^{CPE} - U^{DE}$ wrt γ

γ	$H_{t+1}^{CPE} - H_{t+1}^{DE}$	$U^{CPE} - U^{DE}$
0.01	5.593×10^6	0.939
0.05	5.335×10^6	0.646
0.1	4.687×10^6	0.316
0.15	3.355×10^6	0.069
0.2	962431	-0.020

Table D4. Sensitivity analysis of $H_{t+1}^{CPE} - H_{t+1}^{DE}, U^{CPE} - U^{DE}$ wrt δ

δ	$H_{t+1}^{CPE} - H_{t+1}^{DE}$	$U^{CPE} - U^{DE}$
0.25	5.290×10^6	0.274
0.3	4.356×10^6	0.160
0.35	3.355×10^6	0.069
0.4	2.278×10^6	0.006
0.45	1.150×10^6	-0.022

Table D5. Sensitivity analysis of $H_{t+1}^{CPE} - H_{t+1}^{DE}, U^{CPE} - U^{DE}$ wrt A

A	$H_{t+1}^{CPE} - H_{t+1}^{DE}$	$U^{CPE} - U^{DE}$
0.1	5.605×10^6	0.961
0.5	4.552×10^6	0.275
1	3.355×10^6	0.069
1.5	2.292×10^6	-0.001
2	1.361×10^6	-0.021

Table D6. Sensitivity analysis of $H_{t+1}^{CPE} - H_{t+1}^{DE}, U^{CPE} - U^{DE}$ wrt h_t

h_t	$H_{t+1}^{CPE} - H_{t+1}^{DE}$	$U^{CPE} - U^{DE}$
60	1.632×10^6	0.019
80	2.474×10^6	0.045
100	3.355×10^6	0.069
120	4.265×10^6	0.091
140	5.196×10^6	0.110

Table D7. Sensitivity analysis of $H_{t+1}^{CPE} - H_{t+1}^{DE}, U^{CPE} - U^{DE}$ wrt N

N	$H_{t+1}^{CPE} - H_{t+1}^{DE}$	$U^{CPE} - U^{DE}$
10^3	45486.1	0.274
10^4	403771	0.160
10^5	3.355×10^6	0.069
10^6	2.469×10^7	0.006
10^7	1.369×10^8	-0.021

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