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Public education and the environment

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Abstract

This paper investigated, in an overlapping generations model highlighting two-period lived households, the influence of education and environmental awareness on physical capital and environmental terms by sketching, at the stable steady-state equilibrium, the comparative static examination. According to this approach, the study has shown that public education policy can neither boost environmental quality standards nor the capital stock. The study also found that larger environmental awareness as young results in upper capital accumulation and upper environmental quality. Regarding individuals' environmental awareness in old age, it was revealed that it leads on the one hand to less physical capital accumulation and on the other hand to a better environmental quality, only in the case where the value of environmental awareness at a young age is 10 and the value of environmental awareness at old age is greater than or equal to 40.

Keywords: Capital accumulation; environmental awareness; environmental quality; public education

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1. Introduction

In the last few years, the discussion about climatic fluctuations has been revived since environmental and socio-economic repercussions are currently writ larger. Nowadays, the discussion about climate emergency is among the most prevailing public issues in both developed and developing nations. To fight climatic fluctuations, policymakers have at their disposition several economic policy instruments geared towards reaching this result. The most noticeable are pollution taxation and public pollution-reducing measures (e.g., water purifying, renewable energy investment, forests stewardship, etc.), both of which have been conceived to decrease the environmental consequences of economic activities (Roudavski & Rutten, 2020).

Governments may as well spend on another sort of policy instrument that orients towards improving climate control only by changing individual attitudes. In particular, expenditure on education might be used as an indirect involvement to preserve the climate, as educational achievement improves environmental awareness. Since the Rio Summit in 1992, education has been seen as a crucial tool for environmental conservation and economic sustainability. Cultured people can be further aware of ecological challenges and therefore can have attitudes and habits in support of environmental enhancement (Meschini et al., 2021). Categorized as an underlying reason behind economic development, education seems as well to be a means to arousing environmental preservation (Alsharif & Ofori-Darko, 2024; Osuntuyi & Lean, 2022). Hence, education is considered a policy instrument that must do its part in fighting climatic fluctuations.

The remainder of this paper is structured as follows. In Section 2, theoretical issues and empirical evidence concerning earlier investigations are addressed. In Section 3, the suggested model is introduced. In Section 4, the equilibrium is displayed. In Section 5, the steady state and its comparative static behavior are sketched. Section 6 wraps up the conclusions and offers concluding remarks and outstanding notes about the elaborated model.

1.1. Theoretical background

Empirical studies corroborate the thesis that knowledge and awareness about ecological problems get better as the household's education level rises. For example, Bimonte (2002) demonstrated that raising people's education is usually followed by improvements in their choices preferring an increased level of environmental preservation. For a given income, the minimum standard of environmental quality that a nation needs are increased by education. Furthermore, Hettige et al., (1996) argued that in the absence of efficient public policies, societies with higher learning adopt supporting measures to manage or limit pollutant release. Despite the relative agreement on the beneficial impact of education, numerous researchers suppose that education is an element that leads to pollution. Educated societies have higher revenue and buying power and are stimulated by an overconsumption of material assets. They yearn to live well by gathering material assets without worrying about the effects of this satisfaction, and the conceptual model of "consume more to be happier" (Princen, 2001) is characterized by publicity and the media resulting in higher physical asset consumption. Since overconsumption of products is a component of the over-use of natural resources, the literate population gives rise to environmental deterioration (climate warming, acid rain and increase in seawater level, ozone layer depletion, among other things).

In exploring policies that focus on consumer habits, it is in particular appropriate to discuss the contribution of individuals' preferences for the environment, which specify in what way individuals deal with pollution. From this perspective, Bednar-Friedl (2012) indicated that environmental orientations, and mainly differences in these orientations between emerging and industrialized countries, are key drivers in establishing the particular environmental policy that optimizes welfare. In an overlapping generations (OLG) setup, the relationship between education, environmental awareness, and growth was handled by Prieur and Bréchet (2013). They concluded, with constant environmental awareness, that given the tax rate is initially under a critical edge as regards the share of human capital in output, education improvement enables the economy to benefit from greater growth and an enhancement of the environment. Schumacher and Zou (2015) studied the situation where a pollution limit establishes the extent to which consumers appreciate the environment. The authors depicted that the level of this limit is a determining factor of the long-term comportment of the economy, the quality of the environment, and economic fluctuations. In another recent article, Constant and Davin (2019) and Ansu-Mensah (2021) investigated, when green preferences are endogenously influenced by education and pollution, the link between environmental regulation and growth. They realized that environmental regulation can extract the oscillations, resulting from the inequalities between generations, as well as boost the long-term growth rate. Nevertheless, this result requires that the revenue from the tax rate has to be aimed at education and direct nature preservation simultaneously.

1.2. Purpose of study

This paper aims to emphasize also on environmental problems and develop an OLG model to investigate the impacts that environmental awareness and education can generate on the environment and the capital by examining, at the stable steady-state equilibrium, the comparative static study.

2. Methods and materials

2.1. The model

2.1.1. The households

We consider an OLG model highlighting two-period lived households. In each period t = 1, 2, ..., a new generation is born. We assume that the population growth is constant and the size of each generation is normalized to one. The stock of knowledge is accumulated about the following constant returns process (Glomm and Ravikumar, 1997):

$$H_{t+1} = G(H_t, E_t) \tag{1}$$

where E_t is the governmental expenditure on education at time t.

The household is awarded with H_t units of human capital in the first period. Education is thus entirely at the expense of the government. Consequently, the latter taxes, at a uniform tax rate, both earnings and the interests on savings. During the first period of life (termed “youth”), the household disseminates knowledge H_t to firms for a real income $\omega_t H_t$. She/he allocates this income net of taxes to savings s_t, consumption c_t^1 and maintenance m_t taking as given the tax rate τ. During the second period of life (“old age”), the household allocates her/his savings to firms and receives the return of savings $R_{t+1}s_t$ (with $R_{t+1} = 1 + (1-\tau)r_{t+1}$ the interest factor). Her/his earnings are completely conducive to the consumption c_{t+1}^2. The budget constraint of generation t when young and when old is expressed as follows:

$$(1-\tau)\omega_t H_t = c_t^1 + s_t + m_t \tag{2}$$

$$c_{t+1}^2 = [1 + (1-\tau)r_{t+1}]s_t \tag{3}$$

Additionally, we assume the government's budget, when young, is balanced:

$$E_t = \tau(\omega_t H_t + r_t s_{t-1}) \tag{4}$$

The environment is assumed to be a public good that is degraded by consumption although can be improved by maintenance spending. This mechanism is depicted as follows (John and Pecchenino, 1994):

$$Q_{t+1} = (1-\rho)Q_t - \beta(c_t^1 + c_t^2) + \gamma m_t \tag{5}$$

where $Q_t(Q_{t+1})$ is the index of environmental quality in period $t(t+1)$, $\rho \in (0,1)$ characterizes the natural rate of environmental degradation, $\beta > 0$ defines the consumption externalities, $c_t^1 + c_{t+1}^2$ is the aggregate consumption in period t, $\gamma > 0$ describes the technology for environmental preservation, and m_t is the aggregate conservation spending intended for the environment in period t. The preservation action in period t is carried out by generation t as this latter can benefit from the environmental enhancement in its dotage.

According to John and Pecchenino (1994), the lifetime utility of individual i born at time t is given by:

$$\mathrm{X} = U(c_t^1) + \delta V(c_{t+1}^2; Q_{t+1}) \tag{6}$$

where $\delta > 0$ denotes the psychological discount factor, and it is identical for all individuals. The individual chooses $c_t^1; s_t; m_t$ and c_{t+1}^2 to maximize utility (6) subject to the two budget identities (2) and (3). Utility (6) meets the following assumption:

Assumption 1 (Utility) The utility function $\mathrm{X} : R_+^3 \Rightarrow R$ is defined over non-negative consumption throughout the working and retirement period along with environmental quality. It is twice continuously differentiable, increasing in all arguments, and strictly concave. It specifically satisfies: $U'_{c_t^1} > 0; V'_{c_{t+1}^2} > 0; V'_{Q_{t+1}} > 0$ and $U''_{c_t^1} < 0; V''_{c_{t+1}^2} < 0; V''_{Q_{t+1}} < 0$. Lastly, to obtain interior solutions, we consider that $\lim_{c^1 \to 0} U'_{c^1} = +\infty$, $\lim_{c^2 \to 0} V'_{c^2} = +\infty$ and $\lim_{Q \to 0} V'_Q = +\infty$.

2.1.2. Activity of the firm

The representative firm employs physical capital K_t and skilled labor L_t^s to produce the final good Y_t:

$$Y_t = F(K_t, L_t^s), \tag{7}$$

where L_t^s characterizes the stock of human capital H_t time the total of unskilled labor L_t. The production function per worker is given by $f(k_t)$ with $k_t = K_t / L_t^s$ the capital-skilled labor ratio. We also suppose that the output per worker, $f(k_t)$, carries out the standard neoclassical properties.

Assumption 2 (Production) The production function $f: R_+ \Rightarrow R_+$ possesses the following properties. It is twice continuously differentiable, increasing, and strictly concave. Particularly, $f'(k_t) > 0$; $f''(k_t) < 0$; $kf''(k) + f'(k) > 0 \; \forall k > 0$. Furthermore, we assume that $\lim_{k \to \infty} f'(k_t) = 0$, $\lim_{k \to 0} f'(k_t) = \infty$ and $f(0) = 0$.

Under the assumption of perfect consumption and the firm's profit maximization behavior, the marginal production of capital and labor accord with factor price. Subsequently, from the definition of production function, the wage ω_t at period t and the rental rate of capital, r_t, are shown as follows:

$$\omega_t = f(k_t) - k_t f'(k_t) \tag{8}$$

$$r_t = f'(k_t) - \sigma \tag{9}$$

We suppose that capital does not depreciate: $\sigma = 0$.

Generation t chooses $\{c_t^1, c_{t+1}^2, s_t, m_t\}$ to maximize its utility subject to the law of motion of environmental quality (5) and the budget constraint of generation t when young and when old (2) and (3). The optimality conditions are written as

$$U'_{c_t^1}(c_t^1) = \delta(\gamma + \beta) V'_{Q_{t+1}}(c_{t+1}^2, Q_{t+1}) \tag{10}$$

$$V'_{c_{t+1}^2}(c_{t+1}^2, Q_{t+1}) = \frac{\gamma}{1 + (1-\tau) r_{t+1}} V'_{Q_{t+1}}(c_{t+1}^2, Q_{t+1}) \tag{11}$$

Equation (10) advocates that the young household chooses consumption in an attempt to equate the marginal rate of substitution between consumption at the first period of life and environmental quality when she/he is old, i.e., $U'_{c_t^1} / \delta V'_{Q_{t+1}}$, and the marginal rate of transformation $(\gamma + \beta)$.

Equation (11) presents an arbitrage between the return rate on the private savings, $[1 + (1-\tau) r_{t+1}]$, and the return rate on environmental expenditure, γ. This condition claims that the household chooses savings to equate the marginal rate of substitution between consumption when she/he is old and environmental quality when she/he is old, i.e., $V'_{c_{t+1}^2} / V'_{Q_{t+1}}$, and the rate of transformation $\gamma / [1 + (1-\tau) r_{t+1}]$.

2.1.3. Competitive equilibrium

An intertemporal competitive equilibrium corresponds to a sequence of per capita variables $\{c_t^1, c_{t+1}^2, s_t, m_t\}$, aggregate variables and prices $\{K_t, H_t, Q_t, E_t\}$ where we have optimum individuals and firms i.e. the FOCs (10), (11), and the equations (8) and (9), for profit maximization, are fulfilled. Furthermore, we have full market clearing i.e., $L_t = 1$ implying $L_t^s = H_t$ and $K_{t+1} = s_t$. The budget identities (2) and (3) are fulfilled. The public fiscal (4) is balanced. Finally, the dynamics of human capital and environmental quality are expressed respectively by (1) and (5).

The entire equilibrium sequences of our model can be understood if we recognize the equilibrium paths for the capital level k and the environmental quality Q. Accordingly, we can highlight the dynamics of capital accumulation and the environmental quality.

We have got to review the likelihood of sustainable long-run growth. We provide a technical assumption on the functional form of the utility for simplification purposes. We typify the elasticity parameters between consumption and environmental quality in line with Zhang's (1999) research as

$$\xi_1 = \frac{Q}{c^1}\frac{V_Q^{'}}{U_{c^1}^{'}} > 0 \tag{12}$$

$$\xi_2 = \frac{Q}{c^2}\frac{V_Q^{'}}{U_{c^2}^{'}} > 0 \tag{13}$$

These parameters denote the individuals' environmental awareness when young and old, respectively. $1/\xi_1$ and $1/\xi_2$ can thought to be the importance assigned by individuals to consumption $c^1$and c^2 relative to Q.

Under the hypothesis (12)- (13) and the assumption that $m > 0$, the FOCs of the household's optimization problem (8) and (9) might be formulated in the following way

$$Q_{t+1} = \delta(\gamma + \beta)\xi_1 c_t^1 \tag{14}$$

$$[1 + (1 - \tau)r_{t+1}]Q_{t+1} = \gamma\xi_2 c_{t+1}^2 \tag{15}$$

Equations (14) and (15) signify that there is a fixed proportion between the consumption level of the household and the index of environmental quality.

We can rewrite equation (15) as

$$c_{t+1}^2 = \frac{[1 + (1 - \tau)r_{t+1}]Q_{t+1}}{\gamma\xi_2} \tag{16}$$

We can recognize a relationship between $k_{t+1}$and Q_{t+1} by taking the savings market clearing condition into account

$$k_{t+1} = \frac{Q_{t+1}}{\gamma\xi_2 H_{t+1}} \tag{17}$$

Getting rid of m_t from equation (2) and substituting it along with (14) and (17) (lagged one period) into (6), we obtain

$$\begin{aligned} Q_{t+1} = (1-\rho)Q_t - \beta\left\{\frac{Q_{t+1}}{\delta(\gamma+\beta)\xi_1} + \frac{[1+(1-\tau)r_t]Q_t}{\gamma\xi_2}\right\} \\ + \gamma\left\{(1-\tau)H_t[f(k_t) - k_t f^{\,\prime}(k_t)] - \frac{Q_{t+1}}{\gamma\xi_2} - \frac{Q_{t+1}}{\delta(\gamma+\beta)\xi_1}\right\} \end{aligned} \tag{18}$$

Reformulating (18) yields

$$\begin{aligned} Q_{t+1}\left(1 + \frac{\beta}{\delta(\gamma+\beta)\xi_1} + \frac{1}{\xi_2} + \frac{\gamma}{\delta(\gamma+\beta)\xi_1}\right) \\ = (1-\rho)Q_t - \beta[1+(1-\tau)r_t]H_t k_t \\ + \gamma(1-\tau)H_t[f(k_t) - k_t f^{\,\prime}(k_t)] \end{aligned} \tag{19}$$

$$Q_{t+1}\left(1+\frac{1}{\delta\xi_1}+\frac{1}{\xi_2}\right) = (1-\rho)Q_t-\beta[H_tk_t+(1-\tau)H_tk_tf'(k_t)] + \gamma(1-\tau)H_t[f(k_t)-k_tf'(k_t)] \tag{20}$$

We symbolize the capital's share of output as

$$\alpha(k_t)=k_tf'(k_t)/f(k_t)$$

For convenience, we suppose that the parameter α is constant. Because of this assumption, (20) leads to

$$Q_{t+1}\left(\frac{\delta\xi_1\xi_2+\xi_2+\delta\xi_1}{\delta\xi_1\xi_2}\right) = (1-\rho)Q_t-\beta H_tk_t+(1-\tau)H_tf(k_t)[\gamma(1-\alpha)-\beta\alpha] \tag{21}$$

Subsequently, the first-order nonlinear difference equation expresses the dynamic equilibrium as

$$Q_{t+1}=\frac{\delta\xi_1\xi_2}{\delta\xi_1\xi_2+\xi_2+\delta\xi_1}\{(1-\rho)Q_t-\beta H_tk_t+(1-\tau)H_tf(k_t)[\gamma(1-\alpha)-\beta\alpha]\} \tag{22}$$

In this study, we apply a Cobb-Douglas function. By plugging $f(k)=Ak^{\alpha}$ into (22) and using the equation (17), we obtain

$$Q_{t+1}=\frac{\delta\xi_1\xi_2}{\delta\xi_1\xi_2+\xi_2+\delta\xi_1}\left\{(1-\rho)Q_t-\beta\frac{Q_t}{\gamma\xi_2} + A(1-\tau)H_t[\gamma(1-\alpha)-\beta\alpha]\left(\frac{Q_t}{\gamma\xi_2H_t}\right)^{\alpha}\right\} \tag{23}$$

$$Q_{t+1}=\frac{\delta\xi_1[(1-\rho)\gamma\xi_2-\beta]}{\gamma(\delta\xi_1\xi_2+\xi_2+\delta\xi_1)}Q_t+\frac{A(1-\tau)[\gamma(1-\alpha)-\beta\alpha]\xi_1{\xi_2}^{1-\alpha}}{\gamma^{\alpha}(\delta\xi_1\xi_2+\xi_2+\delta\xi_1)}{Q_t}^{\alpha} \tag{24}$$

$$Q_{t+1}=\mu_0Q_t+\mu_1(Q_t)^{\alpha} \tag{25}$$

where

$$\mu_0=\frac{\delta\xi_1[(1-\rho)\gamma\xi_2-\beta]}{\gamma(\delta\xi_1\xi_2+\xi_2+\delta\xi_1)} \quad ; \quad \mu_1=\frac{A(1-\tau)[\gamma(1-\alpha)-\beta\alpha]\xi_1{\xi_2}^{1-\alpha}}{\gamma^{\alpha}(\delta\xi_1\xi_2+\xi_2+\delta\xi_1)}$$

Considering equation (17), we can figure out from (25) a dynamic equation for the evolution of k.

$$\gamma\xi_2H_{t+1}k_{t+1}=\mu_0(\gamma\xi_2H_tk)_t+\mu_1(\gamma\xi_2H_tk_t) \tag{26}$$

By reorganizing, we obtain

$$k_{t+1}=\eta_0k_t+\eta_1k_{t+1} \tag{27}$$

Such that

$$\eta_0=\mu_0\frac{H_t}{H_{t+1}}=\frac{\delta[(1-\rho)\gamma\xi_2-\beta]}{\gamma(\delta\xi_1\xi_2+\xi_2+\delta\xi_1)}\frac{H_t}{H_{t+1}}$$

and

$$\eta_1=\frac{\mu_0}{(\gamma\xi_2)^{1-\alpha}}\frac{{H_t}^{\alpha}}{H_{t+1}}=\frac{A(1-\tau)[\gamma(1-\alpha)-\beta\alpha]\xi_1{H_t}^{\alpha}}{\gamma(\delta\xi_1\xi_2+\xi_2+\delta\xi_1)H_{t+1}}$$

The sign of μ_0, μ_1, η_0 and η_1 determines the existence of a non-trivial steady state. The key condition for μ_1 and η_1 to be nonnegative is: $\gamma>\beta[\alpha(1-\alpha)]$ .Consequently, either better technology for environmental maintenance (higher γ) or lower consumption externalities (lower β) are needed. In other words, for the aim of having a growth path that converges to a non-trivial steady state, preservation efficiency relative to deterioration has to be high enough. μ_0 and $\eta_0$are positive if and only if, $\xi_2>\beta/(1-\rho)\gamma$. Thus, the existence of the steady state seems to be influenced by the old individuals' attitude toward the environment (parameter ξ_2). Studying the stability properties of the long-run equilibrium is important as well. We start by establishing the steady states of the two-dimensional differential system. The existence of two steady states can be easily detected. The first one is trivial, which is

$$\left(\bar{Q}_0,\bar{k}_0\right)=(0,0)$$

The second one is easily acknowledged after some computation. We commence by solving (25).

$$\bar{Q} = \mu_0 \bar{Q} + \mu_1 \bar{Q}^{\alpha}$$

By this

$$\bar{Q}_1 = \left(\frac{\mu_1}{1-\mu_0}\right)^{\frac{1}{1-\alpha}}$$

Likewise, equation (27) gets to

$$\bar{k} = \eta_0 \bar{k} + \eta_1 \bar{k}^{\alpha}$$

and it is resolved by

$$\bar{k}_1 = \left(\frac{\eta_1}{1-\eta_0}\right)^{\frac{1}{1-\alpha}}$$

Hence, the nontrivial fixed point of the induced map can be written as

$$(\bar{Q}_1, \bar{k}_1) = \left(\left(\frac{\mu_1}{1-\mu_0}\right)^{\frac{1}{1-\alpha}}, \left(\frac{\eta_1}{1-\eta_0}\right)^{\frac{1}{1-\alpha}}\right)$$

In light of the topological equivalence between linear and nonlinear systems asserted by the Hartman-Grobman theorem, the stability of the fixed point of the nonlinear system can be characterized by examining the eigenvalues of the Jacobian matrix. We start by setting up the Jacobian matrix of partial derivatives.

$$J_{(Q,k)} = \begin{bmatrix} \frac{\partial Q_{t+1}}{\partial Q_t} & \frac{\partial Q_{t+1}}{\partial k_t} \\ \frac{\partial k_{t+1}}{\partial Q_t} & \frac{\partial k_{t+1}}{\partial k_t} \end{bmatrix}$$

$$J = \begin{bmatrix} \mu_0 + \alpha\mu_1 Q^{\alpha-1} & 0 \\ 0 & \eta_0 + \alpha\eta_1 k^{\alpha-1} \end{bmatrix}$$

We establish now, at the steady state, the Jacobian matrix J.

$$J_{|\,(\bar{Q}_1,\bar{k}_1)} = A = \begin{bmatrix} \mu_0 + \alpha\mu_1\left(\frac{1-\mu_0}{\mu_1}\right) & 0 \\ 0 & \eta_0 + \alpha\eta_1\left(\frac{1-\eta_0}{\eta_1}\right) \end{bmatrix}$$

By solving the characteristic polynomial $z(\lambda) = det(A - \lambda I) = 0$, we derive the eigenvalues.

$$z(\lambda) = \begin{vmatrix} \mu_0 + \alpha(1-\mu_0) - \lambda & 0 \\ 0 & \eta_0 + \alpha(1-\eta_0) - \lambda \end{vmatrix} = 0$$

We get

$$\lambda_1 = \mu_0(1-\alpha) + \alpha$$
$$\lambda_2 = \eta_0(1-\alpha) + \alpha$$

At a steady state, $\eta_0 = \mu_0$. Therefore, $\lambda_1 = \lambda_2$. As stated by Azariadis (1993), if all the eigenvalues of the Jacobian matrix of partial derivatives have moduli strictly less than one i.e., $|\lambda_i| < 1$ for all i, the steady state $(\bar{Q}, \bar{k})$ is asymptotically stable.

For us, we need to confirm that

$$|\mu_0(1-\alpha) + \alpha| < 1 \tag{28}$$

Evidently, μ_0 is positive if and only if $\xi_2 > \beta/(1-\rho)\gamma$. In consequence, equation (28) can be written as

$$\mu_0(1-\alpha) + \alpha < 1 \qquad \forall\, \xi_2 > \beta/(1-\rho)\gamma \tag{29}$$

Equation (29) simplifies to

$$\mu_0 < 1 \qquad \forall\, \xi_2 > \beta/(1-\rho)\gamma$$

We can conclude that the system converges to a long-run equilibrium which is asymptotically stable.

2.1.4. Steady state

In advance of studying the steady state in the broader sense, we characterize the comparative static behavior of the steady state that we can attain under certain assumptions executed on the utility and production functions.

Equation (25) can be expressed as

$$\bar{Q} = \left\{\frac{A(1-\tau)[\gamma(1-\alpha)-\beta\alpha]\xi_1\xi_2{}^{1-\alpha}}{\gamma^{\alpha-1}(\delta\gamma\rho\xi_1\xi_2+\gamma\xi_2+\delta\gamma\xi_1+\delta\beta\xi_1)}\right\}^{\frac{1}{1-\alpha}} = \varphi^{\frac{1}{1-\alpha}} \tag{30}$$

where

$$\varphi = \frac{A(1-\tau)[\gamma(1-\alpha)-\beta\alpha]\xi_1\xi_2{}^{1-\alpha}}{\gamma^{\alpha-1}(\delta\gamma\rho\xi_1\xi_2+\gamma\xi_2+\delta\gamma\xi_1+\delta\beta\xi_1)}$$

Similarly, we rewrite (28) as

$$\bar{k} = \left\{\frac{A(1-\tau)[\gamma(1-\alpha)-\beta\alpha]\xi_1 H^{\alpha-1}}{\delta\gamma\rho\xi_1\xi_2+\gamma\xi_2+\delta\gamma\xi_1+\delta\beta\xi_1}\right\}^{\frac{1}{1-\alpha}} = \psi^{\frac{1}{1-\alpha}} \tag{31}$$

where

$$\psi = \frac{A(1-\tau)[\gamma(1-\alpha)-\beta\alpha]\xi_1 H^{\alpha-1}}{\delta\gamma\rho\xi_1\xi_2+\gamma\xi_2+\delta\gamma\xi_1+\delta\beta\xi_1}$$

We identify now the comparative static behavior of (30) and (31).

3. Results

Proposition 1: Economies with better effectiveness of maintenance (higher γ) benefit from improved environmental quality and accumulate more capital.

Based on the system of equations (30) - (31), we have

$$\begin{aligned}\frac{\partial\bar{Q}}{\partial\gamma} &= \frac{1}{1-\alpha}\varphi^{\frac{\alpha}{1-\alpha}}\left\{\frac{A(1-\tau)\xi_1\xi_2{}^{1-\alpha}\gamma^{\alpha-1}(\delta\gamma\rho\xi_1\xi_2+\gamma\xi_2+\delta\gamma\xi_1+\delta\beta\xi_1)}{[\gamma^{\alpha-1}(\delta\gamma\rho\xi_1\xi_2+\gamma\xi_2+\delta\gamma\xi_1+\delta\beta\xi_1)]^2}\right.\\ &- \frac{A(1-\tau)\xi_1\xi_2{}^{1-\alpha}[\gamma(1-\alpha)-\beta\alpha][(\alpha-1)\gamma^{\alpha-2}(\delta\gamma\rho\xi_1\xi_2+\gamma\xi_2+\delta\gamma\xi_1+\delta\beta\xi_1)]}{[\gamma^{\alpha-1}(\delta\gamma\rho\xi_1\xi_2+\gamma\xi_2+\delta\gamma\xi_1+\delta\beta\xi_1)]^2}\\ &\left.- \frac{A(1-\tau)\xi_1\xi_2{}^{1-\alpha}[\gamma(1-\alpha)-\beta\alpha]\gamma^{\alpha-1}(\delta\rho\xi_1\xi_2+\xi_2+\delta\xi_1+\delta\beta\xi_1)}{[\gamma^{\alpha-1}(\delta\gamma\rho\xi_1\xi_2+\gamma\xi_2+\delta\gamma\xi_1+\delta\beta\xi_1)]^2}\right\}\end{aligned} \tag{32}$$

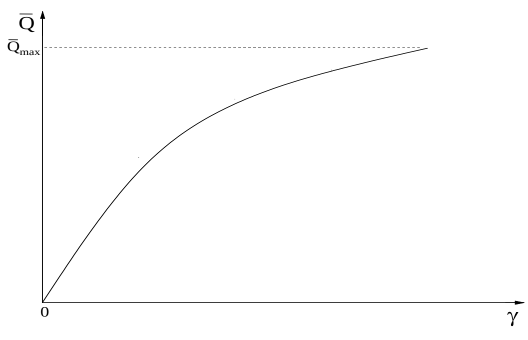
Equation (32) is positive, if and only if

$$\delta\beta\xi_1 + (1-\alpha)\gamma^{\alpha-1}[\gamma(1-\alpha)-\beta\alpha] + \beta\alpha\xi_2(1+\delta\rho\xi_1) > 0$$

which is true under our assumptions.

Fig.1

Impact of γ on environmental quality



$$\frac{\partial\bar{k}}{\partial\gamma}=\frac{1}{1-\alpha}\psi^{\frac{\alpha}{1-\alpha}}\left\{\frac{A(1-\tau)\xi_1H^{\alpha-1}(1-\alpha)(\delta\gamma\rho\xi_1\xi_2+\gamma\xi_2+\delta\gamma\xi_1+\delta\beta\xi_1)}{[\delta\gamma\rho\xi_1\xi_2+\gamma\xi_2+\delta\gamma\xi_1+\delta\beta\xi_1]^2}-\frac{[\gamma(1-\alpha)-\beta\alpha]A(1-\tau)\xi_1H^{\alpha-1}(\delta\rho\xi_1\xi_2+\xi_2)}{[\delta\gamma\rho\xi_1\xi_2+\gamma\xi_2+\delta\gamma\xi_1+\delta\beta\xi_1]^2}\right\} \tag{33}$$

To inspect the effect of γ on $\bar{k}$ we need to examine the sign of the numerator of (33). The numerator of (64) reduces to

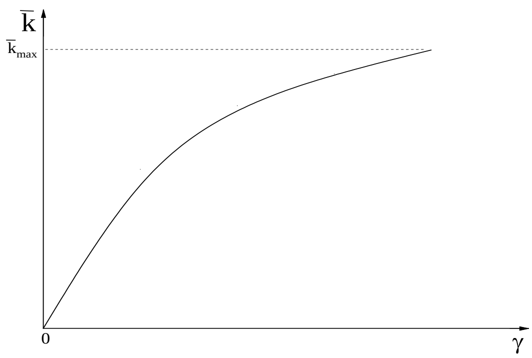
$$(1-\tau)H^{\alpha-1}\left[(1-\alpha)\delta(1+\gamma){\xi_1}^2+\xi_1\xi_2\beta\alpha(\xi_1\delta+1)\right]>0$$

In consequence, we concluded that the impact of γ on $\bar{k}$ is positive.

Ceteris paribus, a society with more environmental maintenance technologies can dedicate a smaller extent to maintenance to reach a certain environmental quality. These assets can be dedicated to capital accumulation. Therefore, both the environment and capital can be maintained at higher standards. This result follows the same path as that reached by John et al., (1995).

Fig.2

Impact of γ on capital accumulation



Proposition 2: *A higher degree of consumption externality (higher β) leads to lower environmental quality and lower capital accumulation.*

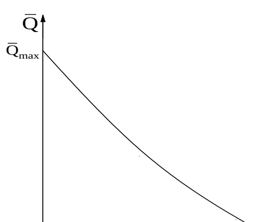
Proof: Consider the system of equations (30) - (31).

$$\frac{\partial\bar{Q}}{\partial\beta}=\frac{1}{1-\alpha}\varphi^{\frac{\alpha}{1-\alpha}}\left\{\frac{-A(1-\tau)\alpha\xi_1{\xi_2}^{1-\alpha}\gamma^{\alpha-1}(\delta\gamma\rho\xi_1\xi_2+\gamma\xi_2+\delta\gamma\xi_1+\delta\beta\xi_1)}{[\gamma^{\alpha-1}(\delta\gamma\rho\xi_1\xi_2+\gamma\xi_2+\delta\gamma\xi_1+\delta\beta\xi_1)]^2}-\frac{\delta\gamma^{\alpha-1}A(1-\tau)\alpha\xi_1{\xi_2}^{1-\alpha}[\gamma(1-\alpha)-\beta\alpha]}{[\gamma^{\alpha-1}(\delta\gamma\rho\xi_1\xi_2+\gamma\xi_2+\delta\gamma\xi_1+\delta\beta\xi_1)]^2}\right\} \tag{34}$$

The numerator of (34) is negative and the denominator is positive given the hypotheses we have made on the parameters. This allows as affirming that the marginal impact of β on $\bar{Q}$ is negative.

Fig.3

Impact of β on environmental quality



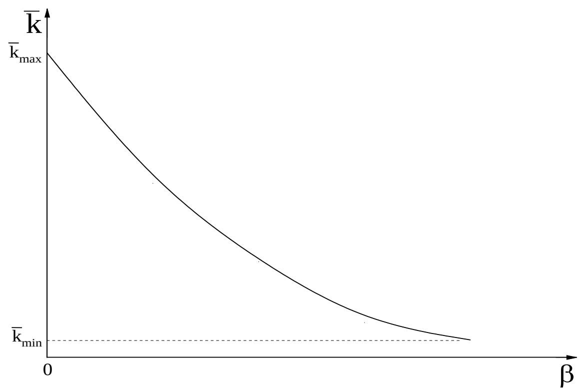
$$\frac{\partial \bar{k}}{\partial \beta} = \frac{1}{1-\alpha}\psi^{\frac{\alpha}{1-\alpha}}\left\{\frac{-AH^{\alpha-1}(1-\tau)\alpha(\delta\gamma\rho\xi_1\xi_2+\gamma\xi_2+\delta\gamma\xi_1+\delta\beta\xi_1)}{[\delta\gamma\rho\xi_1\xi_2+\gamma\xi_2+\delta\gamma\xi_1+\delta\beta\xi_1]^2} - \frac{AH^{\alpha-1}(1-\tau)[\gamma(1-\alpha)-\beta\alpha]\delta\xi_1}{[\delta\gamma\rho\xi_1\xi_2+\gamma\xi_2+\delta\gamma\xi_1+\delta\beta\xi_1]^2}\right\} \quad (35)$$

We detect the impact of β on $\bar{k}$ from equation (35) which is negative.

If every unit of consumption produces bigger environmental depreciation, then the young have to dedicate more assets to environmental preservation, leaving fewer resources for saving and consumption. Such a result follows a similar path to that reached by John and Pecchenino (1995) however disagree, for example, with that reached by Gutierrez (2008). In her study, pollution causes individuals to undergo medical expenses in old age. Consequently, in this instance, a higher environmental deterioration means a higher medical expense that leads individuals to save more when they are elderly and this suggests that the economy accumulates more capital. As for Ono and Maeda (2002), higher β results in a lower per capita environmental quality if the relative risk aversion is greater than one.

Fig.4

Impact of β on capital accumulation



Proposition 3: *Societies with higher values of the natural rate of deterioration of the environment (higher ρ) accumulate lower capital levels and possess worse environmental quality.*

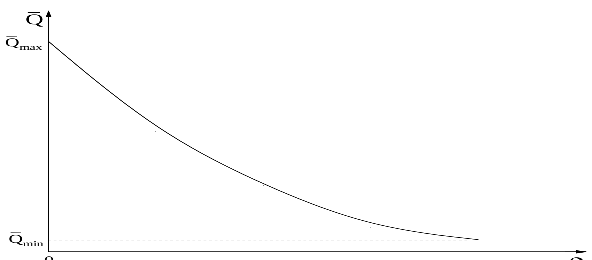
Proof: Let's examine the system of equations (31) - (32).

$$\frac{\partial \bar{Q}}{\partial \rho} = \frac{1}{1-\alpha}\varphi^{\frac{\alpha}{1-\alpha}}\left\{\frac{-A(1-\tau)\xi_1\xi_2^{1-\alpha}[\gamma(1-\alpha)-\beta\alpha]\delta\gamma^{\alpha-1}\xi_1\xi_2}{[\gamma^{\alpha-1}(\delta\gamma\rho\xi_1\xi_2+\gamma\xi_2+\delta\gamma\xi_1+\delta\beta\xi_1)]^2}\right\} \quad (36)$$

We note that the denominator of (36) is positive. Concerning the numerator, it is negative. Accordingly, the marginal effect of ρ on $\bar{Q}$ is negative.

Fig.5

Impact of ρ on environmental quality



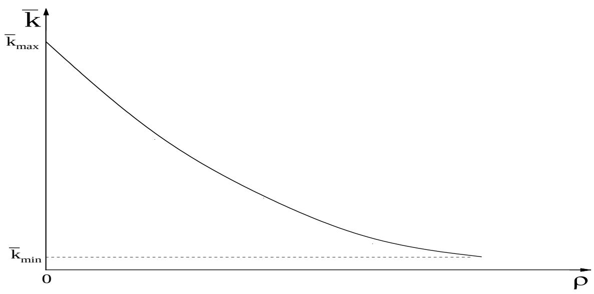
$$\frac{\partial \bar{k}}{\partial \rho} = \frac{1}{1-\alpha}\psi^{\frac{\alpha}{1-\alpha}}\left\{\frac{-AH^{\alpha-1}(1-\tau)\xi_1[\gamma(1-\alpha)-\beta\alpha]\delta\gamma\xi_1\xi_2}{[\delta\gamma\rho\xi_1\xi_2+\gamma\xi_2+\delta\gamma\xi_1+\delta\beta\xi_1]^2}\right\} \tag{37}$$

Under our hypotheses on the parameters, we can assert that the impact of ρ on $\bar{Q}$ is negative.

A lower natural rate of deterioration of the environment reveals a lower future environmental quality for any given stock of capital. As a result, young individuals need to face greater maintenance spending to maintain the environmental quality invariable. The higher cost causes individuals to save less which in turn means that the economy accumulates lower capital levels and deteriorates further the environment. John and Pecchenino (1995) obtain the same outcome.

Fig.6

Impact of ρ on capital accumulation



Proposition 4: *Societies with higher environmental awareness when young (higher ξ_1), accumulate higher capital levels, and enjoy a better environmental quality.*

Proof: Let's examine the system of equations (31) - (32).

$$\frac{\partial \bar{Q}}{\partial \xi_1} = \frac{1}{1-\alpha}\varphi^{\frac{\alpha}{1-\alpha}}\left\{\frac{A(1-\tau){\xi_2}^{1-\alpha}[\gamma(1-\alpha)-\beta\alpha]\gamma^{\alpha-1}(\delta\gamma\rho\xi_1\xi_2+\gamma\xi_2+\delta\gamma\xi_1+\delta\beta\xi_1)}{[\gamma^{\alpha-1}(\delta\gamma\rho\xi_1\xi_2+\gamma\xi_2+\delta\gamma\xi_1+\delta\beta\xi_1)]^2} - \frac{A(1-\tau){\xi_2}^{1-\alpha}[\gamma(1-\alpha)-\beta\alpha]\xi_1\delta\gamma^{\alpha-1}(\gamma+\gamma\rho\xi_2+\beta)}{[\gamma^{\alpha-1}(\delta\gamma\rho\xi_1\xi_2+\gamma\xi_2+\delta\gamma\xi_1+\delta\beta\xi_1)]^2}\right\} \tag{38}$$

$$\frac{\partial \bar{k}}{\partial \xi_1} = \frac{1}{1-\alpha}\psi^{\frac{\alpha}{1-\alpha}}\left\{\frac{AH^{\alpha-1}(1-\tau)[\gamma(1-\alpha)-\beta\alpha](\delta\gamma\rho\xi_1\xi_2+\gamma\xi_2+\delta\gamma\xi_1+\delta\beta\xi_1)}{[\delta\gamma\rho\xi_1\xi_2+\gamma\xi_2+\delta\gamma\xi_1+\delta\beta\xi_1]^2} - \frac{AH^{\alpha-1}(1-\tau)[\gamma(1-\alpha)-\beta\alpha]\xi_1\delta(\gamma+\gamma\rho\xi_2+\beta)}{[\delta\gamma\rho\xi_1\xi_2+\gamma\xi_2+\delta\gamma\xi_1+\delta\beta\xi_1]^2}\right\} \tag{39}$$

Resting upon the hypothesis that $\xi_2 > 0$, (38), and (39) are positive.

A higher value of ξ_1 indicates that individuals choose to substitute consumption when young with environmental quality when old. If consumption is lowered, at that moment the damaging effects of consumption on the environment are reduced and the environmental quality is better, ceteris paribus. On the other side, if the consumption level at a young age is reduced, then savings are increased thus the society accumulates higher capital. This result mimics that found by Balestra (2007).

Fig.7

Impact of ξ_1 on environmental quality

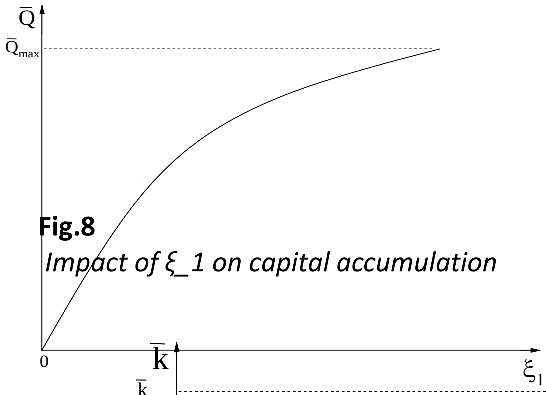
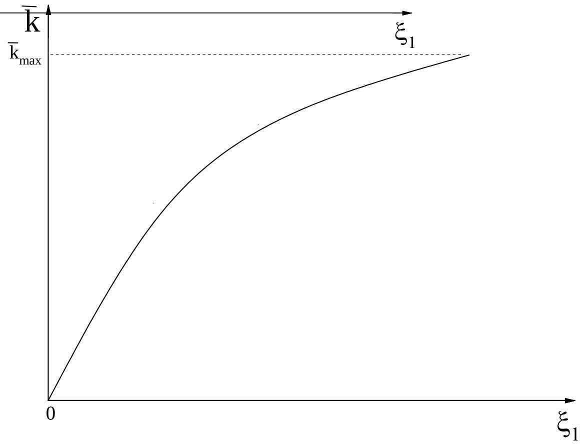


Fig.8

Impact of ξ_1 on capital accumulation



Proposition 5: *Societies with higher environmental awareness when old (higher ξ_2) accumulate lower capital levels, while the impact on the environmental quality is positive if* ξ_1=10 and $\xi_2 \geq 40$.

Proof: Shall we study the system of equations (31) - (32).

$$\frac{\partial \bar{Q}}{\partial \xi_2} = \frac{1}{1-\alpha}\varphi^{\frac{\alpha}{1-\alpha}}\left\{\frac{A(1-\tau)(1-\alpha)\xi_1{\xi_2}^{1-\alpha}[\gamma(1-\alpha)-\beta\alpha]\gamma^{\alpha-1}(\delta\gamma\rho\xi_1\xi_2+\gamma\xi_2+\delta\gamma\xi_1+\delta\beta\xi_1)}{[\gamma^{\alpha-1}(\delta\gamma\rho\xi_1\xi_2+\gamma\xi_2+\delta\gamma\xi_1+\delta\beta\xi_1)]^2} - \frac{A(1-\tau)\xi_1{\xi_2}^{1-\alpha}[\gamma(1-\alpha)-\beta\alpha]\delta\gamma^{\alpha}(1+\rho\xi_1)}{[\gamma^{\alpha-1}(\delta\gamma\rho\xi_1\xi_2+\gamma\xi_2+\delta\gamma\xi_1+\delta\beta\xi_1)]^2}\right\} \quad (40)$$

We should verify, for (40) to be positive, that

$$\gamma^{\alpha-1}(\delta\gamma\rho\xi_1\xi_2+\gamma\xi_2+\delta\gamma\xi_1+\delta\beta\xi_1)-\gamma^{\alpha}(1+\delta\rho\xi_1)>0$$

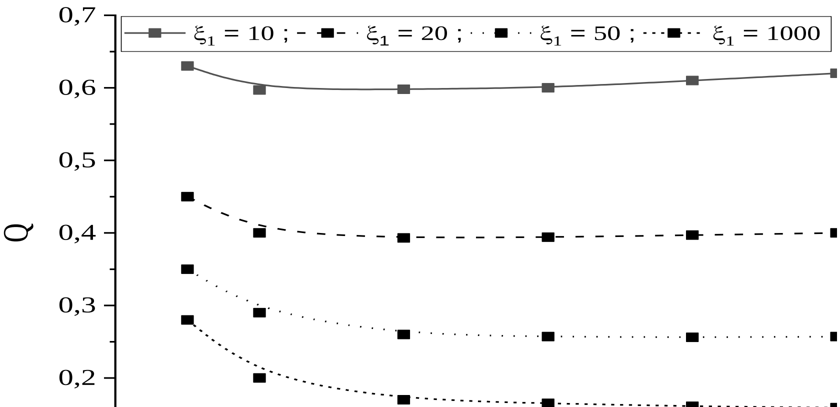
which holds if

$$\xi_2 > 1-\frac{\delta\xi_1(1+\beta\gamma^{-1})}{(1+\delta\rho\xi_1)}$$

Analytically, the effect on the environment is ambiguous. We proceed then with a numerical exercise. For this reason, we choose some parameter values to show visually this effect.

Fig.9

ξ_2 effects on Q for different values of ξ_1



The Fig.9 illustrates the effect of environmental awareness when old ξ_2, on the environment on the steady-state equilibrium, an identical behavior of Q is shown independently of the environmental awareness when young ξ_1. It indicates a continuous evolution that quickly decreases when ξ_2 increases, and this holds for the values of ξ_1=20, 50 and 1000. This decrease is remarkable when ξ_2 varies from 10 to 20. This behavior can be explicated as follows: If the second-period consumption decreases (as a result of a higher ξ_2), then the individuals might decide to consume more during the first period or/and to spend on environmental quality. The negative repercussions of consumption activities outweigh thus the maintenance efforts leading to the environment worsening. A different behavior is observed when ξ_1=10: a decrease, followed by an increase and a subsequent decrease (a minimum followed by a maximum). The environmental quality Q reaches its maximum value of 0.63 for ξ_1=ξ_2=10 and arrives at its minimum value of 0.16 for ξ_1=1000 and ξ_2=100. The decrease of ξ_1 from 1000 to 10 leads to an improvement in the environment for each value of ξ_2. The combined effect of ξ_1 and ξ_2 has a positive influence on the magnitude of Q when ξ_1=10 and $\xi_2 \geq 40$.

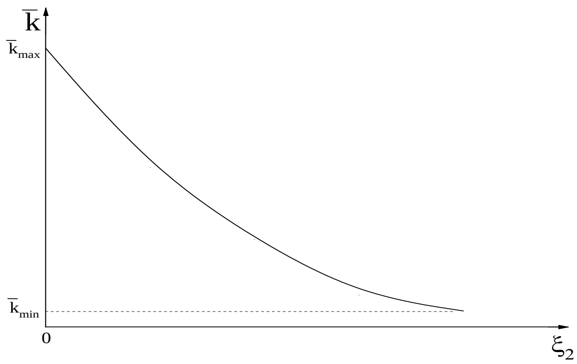
$$\frac{\partial \bar{k}}{\partial \xi_2} = \frac{1}{1-\alpha}\psi^{\frac{\alpha}{1-\alpha}}\left\{\frac{-AH^{\alpha-1}(1-\tau)[\gamma(1-\alpha)-\beta\alpha]\xi_1\gamma(1+\delta\rho\xi_1)}{[\delta\gamma\rho\xi_1\xi_2+\gamma\xi_2+\delta\gamma\xi_1+\delta\beta\xi_1]^2}\right\} \quad (41)$$

Given that the numerator is negative, whereas the denominator is positive, we can easily determine from (41) that the marginal impact of ξ_2 on $\bar{k}$ is always negative.

If the value of ξ_2 is sufficiently large, then the individual chooses to consume less in old age, which implies less savings and the society accumulates lower capital levels.

Fig.10

Effect of ξ_2 on capital accumulation



Proposition 6: *Societies with larger values of tax rate (higher τ) accumulate lower capital levels and possess worse environmental quality.*

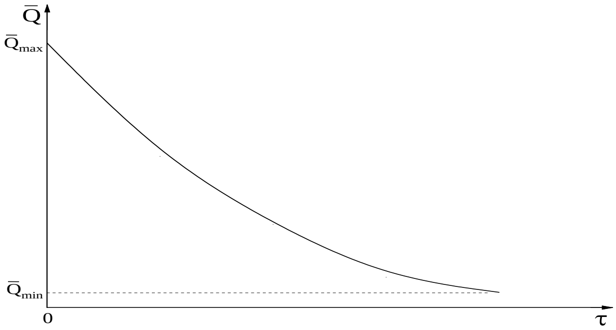
Proof: Let's examine the system of equations (31) - (32).

$$\frac{\partial \bar{Q}}{\partial \tau} = \frac{1}{1-\alpha}\varphi^{\frac{\alpha}{1-\alpha}}\left\{\frac{-A\xi_1{\xi_2}^{1-\alpha}[\gamma(1-\alpha)-\beta\alpha]\gamma^{\alpha-1}(\delta\gamma\rho\xi_1\xi_2+\gamma\xi_2+\delta\gamma\xi_1+\delta\beta\xi_1)}{[\gamma^{\alpha-1}(\delta\gamma\rho\xi_1\xi_2+\gamma\xi_2+\delta\gamma\xi_1+\delta\beta\xi_1)]^2}\right\} \quad (42)$$

We can disclose that, under our hypotheses on the parameters, the impact of τ on $\bar{Q}$ is negative.

Fig.11

Effect of τ on environmental quality

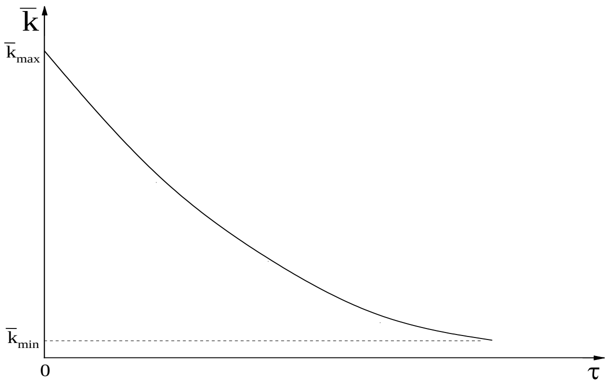


$$\frac{\partial \bar{k}}{\partial \tau} = \frac{1}{1-\alpha}\psi^{\frac{\alpha}{1-\alpha}}\left\{\frac{-AH^{\alpha-1}[\gamma(1-\alpha)-\beta\alpha]\xi_1(\delta\gamma\rho\xi_1\xi_2+\gamma\xi_2+\delta\gamma\xi_1+\delta\beta\xi_1)}{[\delta\gamma\rho\xi_1\xi_2+\gamma\xi_2+\delta\gamma\xi_1+\delta\beta\xi_1]^2}\right\} \quad (43)$$

We observe right away that the denominator of (43) is positive while the numerator is negative, thus the marginal impact of τ on $\bar{k}$ is negative.

Fig.12

Effect of τ on capital accumulation



Higher tax rates indicate that younger agents have fewer resources to consume. When consumption is reduced, the harmful effects of consumption on the environment are reduced and the quality of the environment improves. In addition, the increase in tax rates leads to less maintenance work, which deteriorates the quality of the environment. As for capital accumulation, higher taxes lead to lower capital accumulation due to lower savings. On the other hand, the consumption of the old individual is lower, because the savings return falls, which means a positive impact on the environment. At the same time, however, higher tax rates increase public revenue and encourage government spending on education. Higher human capital means higher output and higher income allocated to individuals. This has harmful effects on the environment. Steady-state characteristics suggest that public spending has a more negative than positive impact on education, which explains environmental degradation. This result is more straightforward and removes the ambiguity of Prieur and Béchet's (2013) results which set specific conditions for the analysis of the environmental impact of public education spending. These authors claim that when taxes fall below the share of human capital produced, tax increases reduce physical capital and environmental quality. If taxes are higher than the share of human capital, the impact of tax increases on physical capital and the environment is ambiguous.

4. Conclusions

Safi, F. (2024). Public education and the environment. *World Journal of Environmental Research*, *14*(1), 1-16. https://doi.org/10.18844/wjer.v14i1.9359

The present paper goes along with models that have incorporated education and environmental awareness in dynamic models. We consider an infinite horizon economy consisting of individuals living both in youth and in old age. Individuals benefit from consumption and environmental quality. The latter are adversely affected by pollution and are a by-product of consumption. Regarding environmental preference, we model environmental awareness as the elasticity between consumption and environmental quality.

We suppose that individuals consume both when young and when old while working only when young. The two authors rather assume that individuals consume only in the second period. Adopting this assumption allows us to tackle the consumption-savings decisions and unveil the compromise between current and upcoming consumption. We assume the externality as stemming from consumption.

In this study, we have realized that the existence of a long-run asymptotically stable equilibrium relies on the intensity of the externality consumption, β, the environmental maintenance technologies, γ and the individuals' environmental awareness at old age ξ_2. Comparative statistics revealed that capital accumulation and environmental quality positively count on environmental maintenance technologies and individuals' environmental awareness at a young age. The natural rate of deterioration of the environment, the externality consumption, and the tax rate hurt both stock variables. At last, the effect of the individuals' environmental awareness in old age on capital is negative. Its impact on the environment is positive when the value of environmental awareness at a young age is 10 and the value of environmental awareness at old age is greater than or equal to 40.

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