Pollution, Health and Life Expectancy: How Environmental Policy Can Promote Growth

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Summary

This article investigates the influence of environmental policy on growth assuming that the channel of transmission relies on the link between pollution, health and the survival probability, in an overlapping generations model à la Blanchard (1985) where growth is driven by a mechanism à la Romer (1986). We demonstrate that environmental policy has an ambiguous effect on growth in the steady-state when the detrimental impact of pollution on health and lifetime is taken into account: for low levels of taxation, environmental policy promotes growth while it is harmful to growth for high levels. Furthermore, we show that the environmental policy is more likely to promote growth (i.e. it stimulates growth for a wider range of environmental taxes) when public expenditures in health and/or the impact of pollution on health are important. Finally, using numerical simulations, we find that for the value of parameters chosen the environmental policy will be more likely to harm growth when agents smooth consumption over time.

Keywords: Growth, Environment, Overlapping generations

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1 INTRODUCTION

Even if the link between environmental policy and growth is a longstanding debate, recent reports upon climate change and the very quick and unbridled industrialization of the biggest economies in the world, such as China and India,[1] have dramatically emphasized the pressing necessity to implement efficient and global environmental policy with an eye towards economic performances.

This article investigates the effect of environmental policy on growth emphasizing the link between pollution, health and life expectancy as the main channel of transmission. It gets away from two observations about the existing literature on the environment and growth. First, as highlighted by Ricci (2007) in a recent survey, the trade-off between environmental quality and growth is negative in both basic AK, R&D-driven growth or human capital accumulation models: reducing pollution to increase the environmental quality turns away resources to investment and therefore drags down growth. To offset this negative effect, it is necessary, for example, either to take into account the external influences of the environment on productivity or some policy-induced adjustments (see Ricci (2007) p. 694), either to assume an influence of environmental policy on savings behaviour or constant returns to scale in the pollution abatement sector (see Michel and Rotillon (1995)). Second, while the detrimental influence of pollution on health is one of the most well-documented phenomenon in the field and one of the most striking features of the negative impact of pollution on individuals,[2] few growth analysis integrate it explicitly.[3]

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[1] From the World Development Indicators (the World Bank), in 2005, India and China grew respectively at an annual rate of 9.23% and 10.20% (in stable increase) while the World and the High income countries grew respectively at 3.48% and 2.66%.

[2] For a survey of studies on pollution and health, see Brunekreef and Holgate (2002), and references in Gutierrez (2005) and Pautrel (in press).

[3] While Gradus and Smulders (1993) justify the negative impact of pollution on human capital accumulation by its effect on health, their formalization seems too rough to enable to capture all the mechanisms at work. Note that the influence of pollution on health has already been accounted for in models that do not investigate its effect on growth. In a continuous time framework, Williams (2002, 2003), for example, studies its impact in terms of environmental taxation assuming that pollution leads to absenteeism due to illness and to higher medical care expenses. In a discrete time framework, Gutierrez (2005), for example, explicitly integrates the

Consequently, in this article, we re-examinate the relation between the environment and growth, taking into account the impact of pollution on health and life expectancy as the main channel of transmission, and without making any assumption about a positive effect of the environmental quality on factors productivity. For this purpose, we use an overlapping generations model *à la* Blanchard (1985) in which we model explicitly the link between pollution and public health and its impact on the lifetime of the agents. Long-run growth is driven by externalities from the aggregate stock of physical capital (AK model *à la* Romer (1986)) and the lifetime of agents depends on public health which is influenced negatively by the level of pollution and positively by public health expenditures.

In this AK model with environmental and health concerns, we demonstrate that environmental policy has an ambiguous effect on growth in the steady-state when the detrimental effect of pollution on health and life expectancy is taken into account. For low levels of taxation, the environmental policy promotes growth because the positive effect of a lower net flow of pollution on health and life expectancy offsets the drag-down effect on the investment due to the increasing tax. For higher levels, the environmental policy becomes harmful to growth because the positive effect of health is defeated by the drag-down effect. We show that the higher public expenditures in health and the greater the impact of pollution on health, the more the environmental policy is likely to promote growth. Furthermore, we demonstrate that when pollution does not affect health, environmental policy remains detrimental to growth whatever the value of the tax, even if the lifetime of agents is finite. Finally, we make numerical simulations to investigate the influence of the intertemporal substitution rate of consumption on our result. We find that, for the value of parameters chosen, the environmental policy is more likely to harm growth when agents smooth consumption over time.

The article is structured as follows. Section 2 gives the basic framework of our model and section 3 formalizes the link between pollution, health and the life expectancy. Section

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link between pollution and health costs for the elderly and shows that pollution makes dynamic inefficiency more likely.

4 investigates the steady-state equilibrium of the economy. Section 5 looks into the impact of environmental taxation on growth and section 6 goes into detail using numerical simulations. Section 7 draws this article to a conclusion.

2 THE ECONOMY'S STRUCTURE

Let us consider an overlapping generations model *à la* Blanchard (1985) with human capital accumulation and environmental concerns. Time is continuous. Each individual born at time s faces a constant probability of death per unit of time $\lambda_s \geq 0$. Consequently, his life expectancy is $1/\lambda_s$. When λ_s increases, the horizon of the economy becomes shorter. At time s, a cohort of size λ_s is born. This cohort has a size equal to $\lambda_s e^{-\lambda_s(t-s)}$ at time t. The constant population is equal to $L_t \equiv \int_{-\infty}^{t} \lambda_s e^{-\lambda_s(t-s)} ds$ at time t. For convenience it is normalized to unity. There are insurance companies and there is no bequest motive.

Contrary to Blanchard (1985), we assume that the probability of death for an agent born at time s depends negatively on the public health in the economy when he is born ε_s. To simplify we pose $\lambda_s = \varepsilon_s^{-1}$.

The expected utility function of an agent born at $s \leq t$ is:

$$\int_s^{\infty} U\left(c_{s,t}, \mathcal{P}_t\right) e^{-(\rho+\lambda_s)(t-s)} dt \tag{1}$$

with

$$U\left(c_{s,t}, \mathcal{P}_t\right) = \begin{cases} \dfrac{\left[c_{s,t}\mathcal{P}_t^{-\phi}\right]^{1-1/\sigma} - 1}{1-1/\sigma} & \sigma \neq 1, \\ \ln c_{s,t} - \phi \ln \mathcal{P}_t & \sigma = 1, \end{cases} \tag{2}$$

where $c_{s,t}$ denotes consumption in period t of an agent born at time s, $\rho \geq 0$ is the rate of time preference and ϕ measures the weight in utility attached to the environment, that is environmental care. σ is the elasticity of intertemporal substitution.

Due to the simple demographic structure, all individual variables are additive across individuals. Consequently, the aggregate consumption equals

$$C_t = \int_{-\infty}^{t} c_{s,t} \lambda_s e^{-\lambda_s (t-s)} ds,$$

The aggregate production function is defined by:

$$Y_t = \tilde{A}_t K_t^{\alpha} L_t^{1-\alpha}, \qquad 0 < \alpha < 1 \tag{3}$$

with Y_t being the aggregate final output. K_t is the aggregate stock of physical capital and L_t is the amount of labor. As discussed in Romer (1986), we assume that there exists external effects of aggregate capital on productivity: $\tilde{A}_t = AK_t^{1-\alpha}$, where $A > 0$ is a constant parameter. Consequently, the aggregate production function reduces to:

$$Y_t = AK_t L_t^{1-\alpha}$$

Finally we assume that the government implements two types of policy: a health policy which consists in publicly providing health services to agents and an environmental policy which consists in taxing the flow of pollution from firms. The government is assumed to balance its budget constraint all the time (see below).

3 POLLUTION, HEALTH AND LIFETIME

Following Gradus and Smulders (1993), pollution flow is assumed to increase with the stock of physical capital K and reduces with abatement activities D:

$$\mathcal{P}_t = \left[\frac{K_t}{D_t} \right]^{\gamma}, \qquad \gamma > 0 \tag{4}$$

We consider that public health at time s is influenced negatively by the net flow of pollution and positively by the part of public health expenditures in GDP:[4]

$$\varepsilon_s = \frac{\beta \theta}{\delta \mathcal{P}_s^{\psi}} \tag{5}$$

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[4] We follow empirical studies which use in their estimations expenditures in health as a percentage of GDP rather than the amount of expenditures in health (see Currais and Rivera (1999), Currais and Rivera (2003) for example).

where θ is the exogenous part of the aggregate final output that the government uses to publicly provide public-health services. $\beta > 0$ is the productivity of the health sector, δ is a positive parameter and $\psi > 0$ measures the influence of pollution on public health.

Abatement activities use final output (one for one) so the final market clearing condition is:

$$(1-\theta)Y_t = C_t + \dot{K}_t + D_t. \tag{6}$$

4 THE GENERAL EQUILIBRIUM AND THE BALANCED GROWTH PATH

In this section, we derive the dynamical system which summarize the intertemporal evolution of the economy and the steady-state defined as a balanced-growth path equilibrium where C, Y, D and K evolve at a common positive rate of growth.

As previously noted, besides its health policy, the government also implements an environmental policy which consists of taxing the net flow of pollution by firms and transferring to them the fruit of the taxes to fund their abatement activities. Consequently, firms under perfect competition pay a pollution tax on their net pollution $\mathcal{P}_t$ and they choose their abatement activities D_t (whose cost equals D_t) and the amount of factors which maximize their profits $\pi_t = Y_t - r_t K_t - w_t L_t - \vartheta_t \mathcal{P}_t - D_t + T_t^p$ where ϑ_t is the pollution tax rate and T_t^p denotes transfers from the public sector with $T_t^p = \vartheta_t \mathcal{P}_t$. Firms take as given these transfers and pay each production factor at its marginal productivity to maximize profit:

$$\begin{aligned} r_t &= \alpha A - \vartheta_t \gamma \frac{\mathcal{P}_t}{K_t} \\ w_t &= (1-\alpha) K_t L_t^{-\alpha} \end{aligned} \tag{7}$$

$$D_t = \vartheta_t \gamma \mathcal{P}_t \tag{8}$$

From equations (4) and (8), we have $\mathcal{P}_t = \left[\gamma \frac{\vartheta_t}{K_t}\right]^{-\gamma/(1+\gamma)}$. Because in the steady-state, the quality of the environment must be constant, ϑ_t must evolve as the physical capital. Intuitively, it increases over time to encourage firms to increase abatement activities to limit pollution which rises with the physical capital stock. Consequently, we define $\tau \equiv \vartheta_t / K_t$, the environmental tax normalized by the physical capital, and following Oueslati (2002) we assume that it is fixed by the government and has no transitional dynamics.[5] Consequently, we obtain:

$$\mathcal{P} = \Phi(\tau)^{-\gamma} \tag{9}$$

with $\Phi(\tau) \equiv [\gamma\tau]^{\frac{1}{1+\gamma}}$ is an increasing function of τ. The net flow of pollution $\mathcal{P}$ is constant over time. Then, equations (7) and (8) may be re-written as (remembering that population is normalized to unity):

$$r = \alpha A - \Phi(\tau) \tag{10}$$

$$w_t = (1 - \alpha) K_t \tag{11}$$

$$D_t = \Phi(\tau) K_t \tag{12}$$

By definition $D_t < K_t$ consequently we impose that $\Phi(\tau) \in]0, 1[$. Furthermore, $r > 0$, therefore we also impose $\alpha A > \Phi(\tau)$.

From (5) and because we assumed $\lambda_t = \varepsilon_t^{-1}$, the probability of death is independent of time and defined by:

$$\lambda = \frac{\delta \Phi(\tau)^{-\psi\gamma}}{\beta\theta} \equiv \mathcal{L}(\tau) \tag{13}$$

where $\mathcal{L}(\tau)$ is a decreasing function of τ.

Households face the following budget constraint:

$$\dot{a}_{s,t} = [r + \lambda]\, a_{s,t} + w_t - c_{s,t} \tag{14}$$

where $a_{s,t}$ is the financial wealth in period t and ω_t represents the wage rate per effective unit of labor.

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[5] Here this assumption is of no consequence inasmuch as the *AK* model has no transitional dynamics.

The representative agent chooses the time path for $c_{s,t}$ by maximizing (1) subject to (14). It gives the consumption at time t of an agent born at time s:

$$c_{s,t} = \Delta(\tau)\left[a_{s,t} + \omega_{s,t}\right] \tag{15}$$

where $\omega_{s,t} \equiv \int_t^\infty w_\nu e^{-(\nu-t)(r+\lambda)} d\nu$ is the present value of lifetime earning and

$$\Delta(\tau) = (1-\sigma)\alpha A - (1-\sigma)\Phi(\tau) + \sigma\rho + \mathcal{L}(\tau) \tag{16}$$

is the propensity to consume the overall individual revenue and is constant over time.[6] By definition the propensity to consume must be positive, consequently we consider that the probability to die is high enough to ensure that $\Delta(\tau)$ is always positive. It implies:

$$\mathcal{L}(\tau) > (1-\sigma)\left[\Phi(\tau) - \alpha A\right] - \sigma\rho \tag{17}$$

Because the interest rate must be positive (that is $\alpha A > \Phi(\tau)$ from equation 10) this conditions is always verified whatever $\mathcal{L}(\tau)$ when $\sigma \leq 1$.

The aggregate consumption equals

$$C_t = \int_{-\infty}^{t} c_{s,t}\lambda e^{-\lambda(t-s)} ds = \Delta(\tau)\left[K_t + \Omega_t\right] \tag{18}$$

with $\Omega_t \equiv \int_{-\infty}^{t} \omega_{s,t}\lambda e^{-\lambda(t-s)} ds$, and the aggregate stock of physical capital is defined by

$$K_t = \int_{-\infty}^{t} a_{s,t}\lambda e^{-\lambda(t-s)} ds \tag{19}$$

Differentiating (18) with respect to time and using the expression of dK_t/dt and $d\Omega_t/dt$ with equations (10) and (13) gives the law of motion of the aggregate consumption:

$$g_{C,t} \equiv \dot{C}_t/C_t = \sigma\left[\alpha A - \Phi(\tau) - \rho\right] - \mathcal{L}(\tau)\Delta(\tau)K_t/C_t \tag{20}$$

Furthermore, the law of motion of the physical capital is:

$$g_{K,t} \equiv \dot{K}_t/K_t = (1-\theta)A - C_t/K_t - \Phi(\tau) \tag{21}$$

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[6] When the interest rate is not constant over time, we have $\int_t^\infty e^{-(\sigma\rho+\lambda)(\nu-t)-(1-\sigma)\int_t^\nu r_\mu d\mu} d\nu$ which is not constant.

Consequently, defining $x_t \equiv C_t/K_t$, the economy is summarized by the two following equations which depends on x_t:

$$\begin{aligned} g_{C,t} &= \sigma\left[\alpha A - \Phi(\tau) - \rho\right] - \mathcal{L}(\tau)\Delta(\tau)x_t^{-1} \\ g_{K,t} &= (1-\theta)A - x_t - \Phi(\tau) \end{aligned} \tag{22}$$

The first equation is an increasing function of x and the second one is an decreasing function. When they intersect they define a unique $x^\star$ which corresponds to the steady-state equilibrium of the economy, where C, K, D and Y grow at a common positive rate $g^\star$ (the star denotes steady-state). Formally, $x^\star$ is the positive solution of the second-order equation $x^{\star 2} + \Omega(\tau)x^\star - \mathcal{L}(\tau)\Delta(\tau) = 0$ that is

$$x^\star = \frac{1}{2}\left\{-\Omega(\tau) + \sqrt{\Omega(\tau)^2 + 4\mathcal{L}(\tau)\Delta(\tau)}\right\} \tag{23}$$

where $\Omega(\tau) \equiv (\theta + \sigma\alpha - 1)A + (1-\sigma)\Phi(\tau) - \sigma\rho < 0$ [7] and $\Delta(\tau) \equiv (1-\sigma)[\alpha A - \Phi(\tau)] + \sigma\rho + \mathcal{L}(\tau)$.

The growth rate in the steady-state is unique and defined as a function of the environmental tax τ:

$$g^\star = (1-\theta)A - \frac{1}{2}\left\{-\Omega(\tau) + \sqrt{\Omega(\tau)^2 + 4\mathcal{L}(\tau)\Delta(\tau)}\right\} - \Phi(\tau) \tag{24}$$

5 ENVIRONMENTAL TAXATION AND GROWTH

To investigate the influence of the environmental taxation on growth, we derive (24) with respect to τ. It gives:

$$\frac{\partial g^\star}{\partial \tau} = \frac{\partial g^\star}{\partial \Phi(\tau)}\frac{\partial \Phi(\tau)}{\partial \tau} \tag{25}$$

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[7] We impose that $\Omega(\tau)$ is positive to have $x^\star$ positive if the lifetime tends to infinity.

where

$$\frac{\partial g^{\star}}{\partial \Phi(\tau)} = \frac{-1}{2}\left\{(1+\sigma)\Phi(\tau) + (1-\sigma)\Phi(\tau)\frac{\Omega(\tau)+2\mathcal{L}(\tau)}{\sqrt{\Omega(\tau)^2+4\Delta(\tau)\mathcal{L}(\tau)}} - 2\gamma\psi\frac{\mathcal{L}(\tau)[\Delta(\tau)+\mathcal{L}(\tau)]}{\sqrt{\Omega(\tau)^2+4\Delta(\tau)\mathcal{L}(\tau)}}\right\} \tag{26}$$

and

$$\begin{aligned}
\Phi(\tau) &\equiv [\gamma\tau]^{\frac{1}{1+\gamma}} \\
\mathcal{L}(\tau) &\equiv \tfrac{\delta}{\beta\theta}\Phi(\tau)^{-\psi\gamma} \\
\Delta(\tau) &\equiv (1-\sigma)[\alpha A - \Phi(\tau)] + \sigma\rho + \mathcal{L}(\tau) > 0 \\
\Omega(\tau) &\equiv (\theta+\sigma\alpha-1)\,A + (1-\sigma)\Phi(\tau) - \sigma\rho < 0
\end{aligned}$$

The function $\Phi(\tau)$ being an increasing function of τ, the influence of the environmental tax is given by the sign of (26).

To clarify as much as possible the mechanisms which operate when pollution affects health and health influences the lifetime of agents, we first expose the case where the lifetime of agents is infinite and the case where lifetime is finite but pollution does not impact health. Hence, we back to the general case exposed in the previous sections and we examinate the effect of environmental taxation on growth when pollution affects health and health influences the lifetime of agents.

5.1 Lifetime is infinite

In this case, the probability of death is independent of the environmental policy because it is null: $\mathcal{L}(\tau) = 0$. The system (22) becomes:

$$g_{C,t} = \sigma\left[\alpha A - \Phi(\tau) - \rho\right]$$

$$g_{K,t} = (1-\theta)A - x_t - \Phi(\tau)$$

The growth rate of the aggregate consumption becomes independent from x and consequently is an horizontal curve which shifts downward when τ increases. The growth rate of the aggregate capital remains a decreasing curve with respect to x and shifts on the left when τ increases. The variation of $x^\star$ depends on the value of σ with respect to 1 because $g_C^\star = g_K^\star$ gives $x^\star = (1-\theta-\sigma\alpha)A + (\sigma-1)\Phi(\tau) + \sigma\rho > 0$. When $\sigma < 1$ (respectively $\sigma > 1$), $x^\star$ decreases (respectively increases) with τ. Nevertheless, the growth rate in the steady-state is given by the first equation of the previous system. It is a decreasing function of the environmental tax rate.

Therefore, we obtain the conventional result of the AK growth model with infinitly-lived agents: environmental policy is always harmful to growth because it reduces the rewards to capital and therefore physical capital accumulation.

5.2 Lifetime is finite but health is not affected by pollution

This case corresponds to $\psi = 0$. Therefore, the probability of death λ does no longer depends on the tax rate τ: $\bar{\lambda} = \dfrac{\delta}{\beta\theta}$. The economy is summarized by:

$$\begin{aligned} g_{C,t} &= \sigma\left[\alpha A - \Phi(\tau) - \rho\right] - \frac{\delta}{\beta\theta}\Delta_\psi(\tau)x_t^{-1} \\ g_{K,t} &= (1-\theta)A - x_t - \Phi(\tau) \end{aligned}$$

with $\Delta_\psi(\tau) = (1-\sigma)\alpha A - (1-\sigma)\Phi(\tau) + \sigma\rho + \dfrac{\delta}{\beta\theta}$. $g_{C,t}$ remains an increasing function of x_t but the influence of τ is not clear-cut. $g_{K,t}$ is not modified.

The influence of the environmental tax on the steady-state rate of growth is then given by the sign of the following expression:

$$\frac{-\Phi(\tau)}{2}\left\{(1+\sigma) + (1-\sigma)\frac{\Omega(\tau)+2\bar{\lambda}}{\sqrt{\Omega(\tau)^2 + 4\Delta(\tau)\bar{\lambda}}}\right\} \tag{27}$$

with $\Omega(\tau) < 0$ for all σ. When $\sigma \leq 1$, $(1-\sigma)\Omega(\tau) \leq 0$, but $\dfrac{\Omega(\tau)}{\sqrt{\Omega(\tau)^2 + 4\Delta(\tau)\bar{\lambda}}} < 1$ consequently $(1+\sigma) + (1-\sigma)\dfrac{\Omega(\tau)}{\sqrt{\Omega(\tau)^2 + 4\Delta(\tau)\bar{\lambda}}} \geq 0$. The term into brackets is positive, therefore $\partial g^\star/\partial\tau < 0$. In the same way, when $\sigma > 1$, $(1-\sigma)\Omega(\tau) \geq 0$ and $(1-\sigma)\dfrac{2\bar{\lambda}}{\sqrt{\Omega(\tau)^2 + 4\Delta(\tau)\bar{\lambda}}} < 0$. Nevertheless $\dfrac{2\bar{\lambda}}{\sqrt{\Omega(\tau)^2 + 4\Delta(\tau)\bar{\lambda}}} < 1$ and therefore $(1+\sigma) + (1-\sigma)\dfrac{2\bar{\lambda}}{\sqrt{\Omega(\tau)^2 + 4\Delta(\tau)\bar{\lambda}}} \geq 0$. The term into brackets is positive, therefore $\partial g^\star/\partial\tau < 0$.

Consequently, when the lifetime of agents is finite but pollution does not affect health status, the environmental policy remains harmful to growth.

5.3 Lifetime is finite and pollution affects health

Because the general case is very cumbersome to study, we only investigate in this preliminary version the case where $\sigma = 1$. Then, $\Delta(\tau)$ is a decreasing function τ and $\Omega(\tau) = \bar{\Omega}$ is independent of τ. Consequently, the influence of the environmental tax on growth is given by the sign of the following expression:

$$\frac{\partial g^\star}{\partial \Phi(\tau)} = -\left\{ \Phi(\tau) - \gamma\psi \frac{\mathcal{L}(\tau)[\rho + 2\mathcal{L}(\tau)]}{\sqrt{\bar{\Omega}^2 + 4\mathcal{L}(\tau)[\rho + \mathcal{L}(\tau)]}} \right\}$$

We obtain $\dfrac{\partial g^\star}{\partial \tau} > 0$ if an only if

$$\gamma\psi \frac{\mathcal{L}(\tau)[\rho + 2\mathcal{L}(\tau)]}{\sqrt{\bar{\Omega}^2 + 4[\rho + \mathcal{L}(\tau)]\mathcal{L}(\tau)}} > \Phi(\tau) \tag{28}$$

with $\Phi(\tau) \equiv [\gamma\tau]^{\frac{1}{1+\gamma}}$ and $\mathcal{L}(\tau) \equiv \frac{\delta}{\beta\theta}\Phi(\tau)^{-\psi\gamma}$.

Because the left-hand side of this inequality is a decreasing function of τ,[8] and the right-hand side is an increasing function of τ, this inequality defines a threshold value $\hat{\tau}$ below which the condition is verified. Therefore, when pollution affects health and health influences life expectancy environmental policy is ambiguous for growth. The link between the environmental policy and growth is a reversed-U shape relation: for low values of the tax, the environmental policy promotes growth and for high values it harms growth.

Consequently, from section 5.2, it is not the finiteness of lifetime by itself which enables the environmental policy to play positively on growth. It is a necessary but not sufficient condition. The sufficient condition is that lifetime is bounded and depends on the environment.

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[8] Its derivative with respect to τ is $\dfrac{\gamma\psi\left[\rho\bar{\Omega}^2 + 2\mathcal{L}(\tau)\left(\rho^2 + 2\bar{\Omega}^2 + 6\rho\mathcal{L}(\tau) + 4\mathcal{L}(\tau)^2\right)\right]}{\left[\bar{\Omega}^2 + 4\mathcal{L}(\tau)(\rho + \mathcal{L}(\tau))\right]^{3/2}} \dfrac{\partial \mathcal{L}(\tau)}{\partial \tau} < 0.$

Using condition (28), it is possible to find the impact of the determinants of the thresold critical value of τ[9]

	δ	θ	β	A	ρ	ψ	γ
$\hat{\tau}$	$+$	$-$	$-$	$-$	$+$	$-$	?

Table 1: Impact of the parameters on $\hat{\tau}$

We investigate further comparative statics in the next section.

6 NUMERICAL SIMULATIONS

This sections aims at answering two questions. First, even if we derived analytically the influence of parameters on the threshold value of the pollution tax, what are their effects on the growth rate in the economy and how do they affect the positive influence of the environmental taxation? Second, what is the influence of the intertemporal elasticity of substitution of consumption σ on the link between the environmental policy and growth?

To answer these questions, we use numerical simulations. We first calibrate the model to obtain realistic values of the probability of death for the US economy and a realistic rate of growth. From the *World Development Indicators 2005* by the World Bank, life expectancy was 77.4 years in 2003, and the public health expenditures as percentage of GDP was 6.55%. Since the expected lifetime is the reverse of the probability of death per unit of time λ, we want λ to be close to $1/77.4 = 0.0129$.

Table 1 summarizes the benchmark value of parameters and Table 2 summarizes the exercise of comparative statics for log utility.

θ	α	δ	ψ	β	ρ	A	γ
0.0655	0.03	0.025	2	20	0.065	0.7	0.3

Table 2: Benchmark value of parameters

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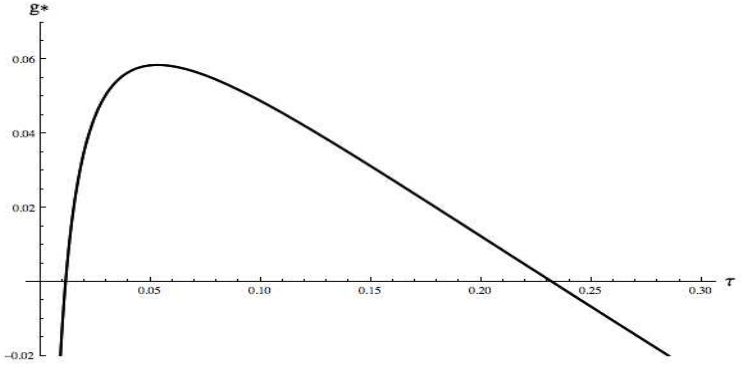
[9] Remembre that $\Phi(\tau) < 1$. See page 4.

The relation between environmental tax and the rate of growth obtained is drawn in Figure 1. The threshold value of the environmental taxation $\hat{\tau}$ is 5.33% and the rate of growth for this value (which is also the maximum rate of growth attainable) equals 5.85%. Note also that $\tau \in]0.01, 0.23[$ to have a positive growth rate in the steady-state.

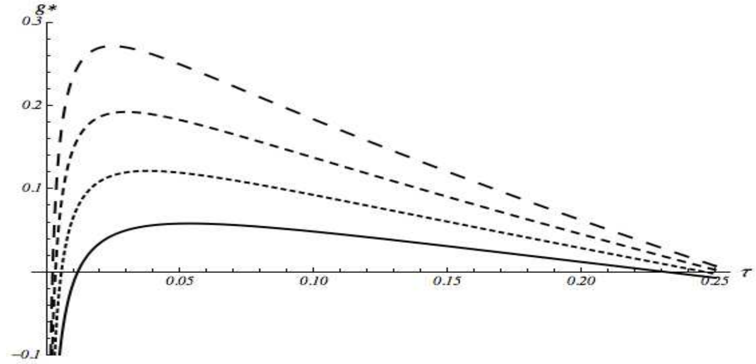
Figure 1: Benchmark case



In the appendix, we report the effects of a variation of the key parameters on the growth rate and on the threshold value of environmental taxation. Numerical simulations show, for example, that a higher public health expenditures in terms of GDP (θ) and a greater productivity in the health sector (β) makes the environmental policy less likely to promote growth. The maximum rate of growth (for an environmental tax equals to $\hat{\tau}$) is greater for all values of the environmental tax. In the same way, when the influence of pollution on health (ψ) increases, the threshold value of the environmental tax rises and the maximum rate of growth is higher. Because these criterions are verified in the most industrialized countries, our results mean that the environmental policy is more likely to promote growth is such a countries.

Finally, we simulate the relation between the growth rate and the environment tax for different values of the intertemporal elasticity of substitution σ. For the values chosen in our numerical simulations, figure 2 and Table 3 in the following confirm our main result

Figure 2: Increase in σ (*the straightline is the benchmark case*)



σ	0.25	0.5	0.75	1	1.5	2	2.5
$\hat{\tau}$	0.1730	0.0948	0.0677	0.0533	0.0379	0.0297	0.0245

Table 3: Impact of an increase in σ

when σ is different from unity: the environmental tax has an ambiguous effect on growth when pollution affects health and health influences the lifetime of agents. Furthermore, the threshold value of the environmental taxation is lower when agents want to smooth their consumption over time (σ is small): the environmental policy is more likely to harm growth in such a case.

7 Conclusion

The aim of this article was to investigate the impact of environmental policy on growth in an AK-type growth model, when the link pollution, health and life expectancy is the main channel of transmission.

We demonstrated that environmental policy has an ambiguous effect on growth in the steady-state when the detrimental effect of pollution on health and lifetime is taken into account. For low levels of taxation, the environmental policy promotes growth because the positive effect of a lower net flow of pollution on health and life expectancy offsets the drag-down effect on the investment due to the increasing tax. For higher levels, the environmental policy becomes harmful to growth because the positive effect of health is defeated by the drag-down effect. Furthermore, we show that the environmental policy is more likely to promote growth when public expenditures in health and/or the impact of pollution on health are more important.. We also make numerical simulations to investigate the influence of the intertemporal substitution rate of consumption on our result. We find that, for the value of parameters chosen, the environmental policy is more likely to harm growth when agents want to smooth consumption over time.

Finally, we demonstrated that the ambiguous impact of environmental policy on growth disappears when the lifetime of agents is finite but pollution does not affect health: environmental policy is always detrimental to growth. Consequently, the key mechanism relies on the features of the health function and the dependence of health to the environment.

Our results militate for an active environmental policy and calls for further investigations on the link between environment and growth, especially incorporating a more realistic health function.

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Appendix

Figure 3: Increase in δ (*the straightline is the benchmark case*)

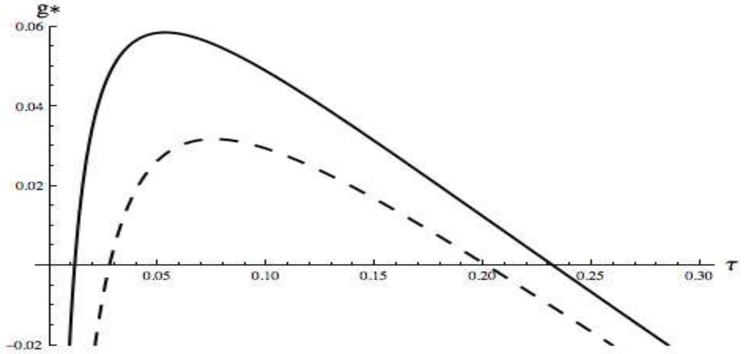


Figure 4: Increase in α (*the straightline is the benchmark case*)

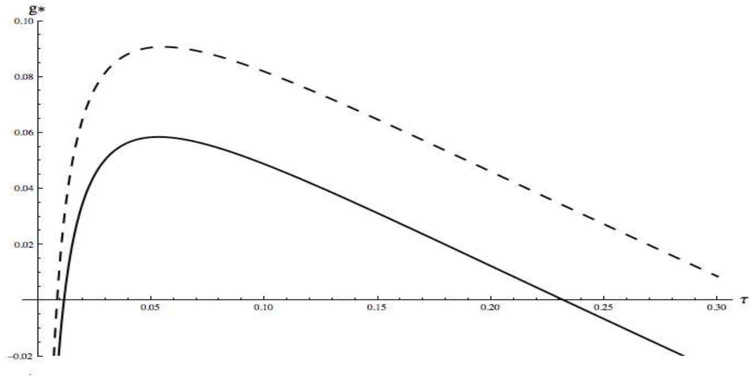


Figure 5: Decrease in ψ (*the straightline is the benchmark case*)

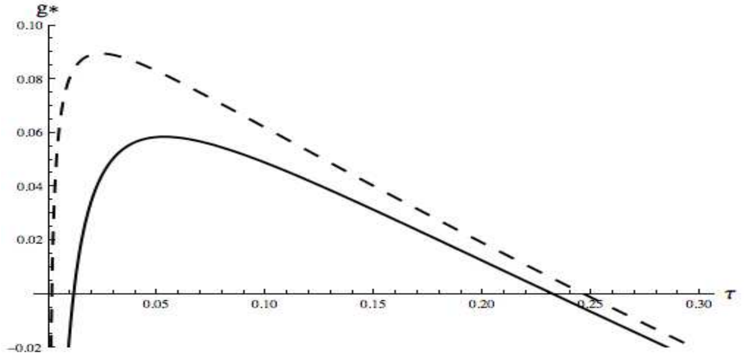


Figure 6: Increase in β (*the straightline is the benchmark case*)

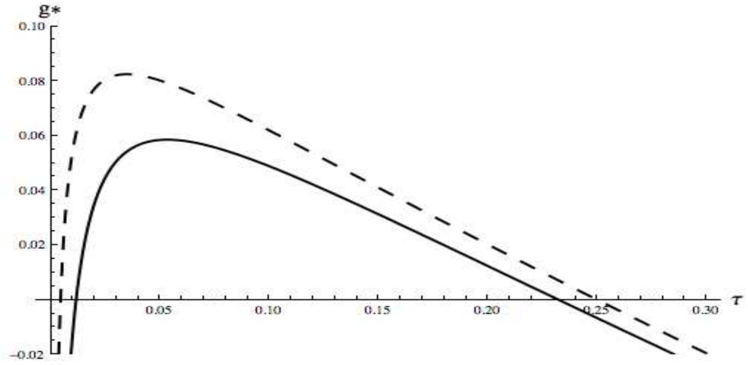


Figure 7: Decrease in ρ (*the straightline is the benchmark case*)

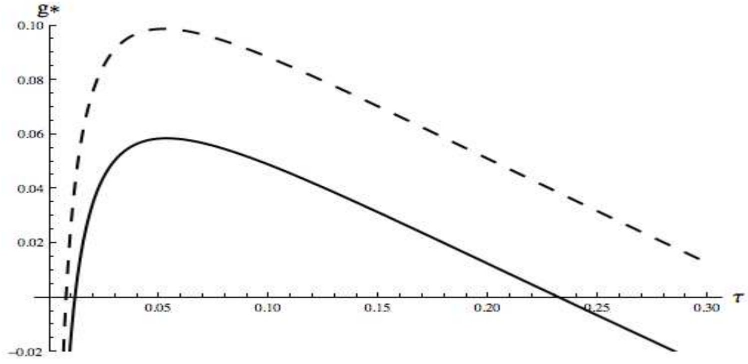


Figure 8: Increase in A (*the straightline is the benchmark case*)

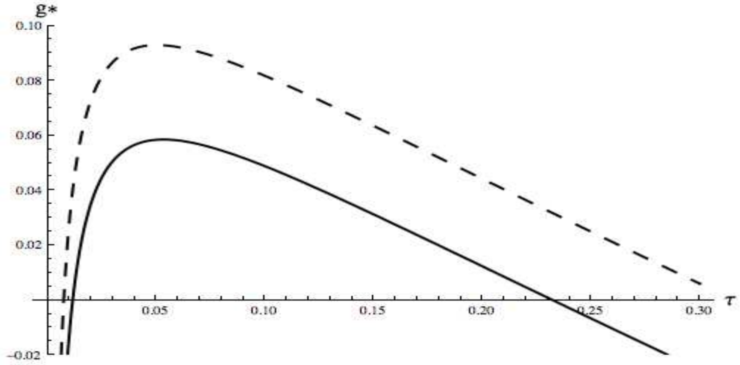


Figure 9: Decrease in γ (*the straightline is the benchmark case*)

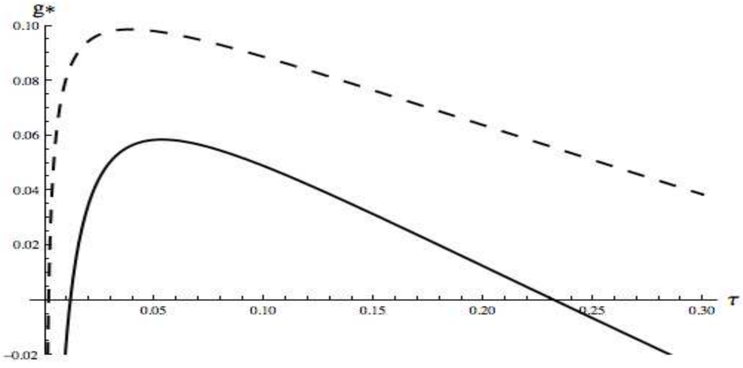
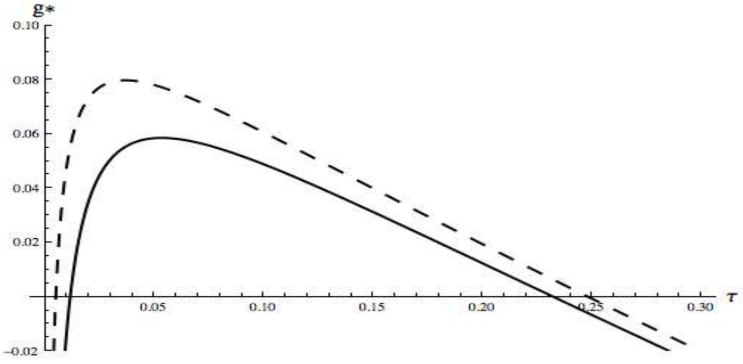


Figure 10: Increase in θ (*the straightline is the benchmark case*)



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