Tax Reforms in an Endogenous Growth Model with Pollution

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Abstract

This paper discusses the effects of a green tax reform in an AK growth model without abatement activities and with a negative environmental externality in the utility function. There is also a non-optimal level of public spending. The results depend on the financing source of public spending. When there is not public debt, a revenue-neutral green tax reform has not any effect on pollution, growth and welfare. On the contrary, when short-run deficits are financed by debt issuing, a variety of green tax reforms increase welfare. Nevertheless, in this new framework, non-green tax reforms are also welfare improving.

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1. INTRODUCTION

We use the simplest endogenous growth model (the AK model) to prove that less distorting tax systems and welfare gains are achievable through 'green tax reforms' when the government can finance a deficit in any period t by issuing one period pure discount bonds. This tax reform is neutral in the sense that the public expenditure path financed before and after the reform does not change.

Currently there exists a debate about the interactions between environmental policies and the tax system. Bovenberg and de Mooij (1994), Bovenberg and Goulder (1996, 1998), Parry and Bento (2000), among others, assume that the public spending requirements exceed the tax revenues that would be generated solely from the pollution taxes if they are set according to the Pigouvian principle, that is, equal to the marginal environmental damages (i.e., there exists non-optimal level of government expenditure). They assume that the public consumption is financed by an environmental tax, a labor tax and a private consumption tax. They used static models to study the effects of a "green tax reform", that is, a translation of taxes revenues from "goods", like labor effort or private consumption, to "bads", like pollution. Revenue-neutral green tax reform, for example, involves increasing the pollution tax and using the new revenues to finance reductions in the rates of other preexisting distortionary revenue-motivated taxes.

The effects of a green tax reform have also been discussed in an endogenous growth model with public investment and abatement activities by Bovenberg and de Mooij (1997). They find that a shift in the tax mix away from output taxes towards pollution taxes may raise economic growth.

We study the effects of a revenue-neutral green tax reform in an AK growth model without abatement activities and with a negative environmental externality in the utility function. There is also a non-optimal level of government spending that can be financed by tax revenues or debt issuing. In this model, two different tax reforms are designed. First, we analyze the revenue-neutral tax reform standard in the literature (away from income tax towards pollution tax). We prove that this policy change has not any effect on pollution, growth or welfare.

Second, our main contribution in the paper is to explore the effects of a deficit-financed tax reform, which has not been studied previously in the literature. In our reform the predetermined path for government expenditure before and after the reform does not change; on the contrary, Bovenberg and de Mooij (1997) substitute environmental taxes for income taxes assuming that government revenues and expenditures must grow at the same rate than the capital stock, so that the expenditure path changes as a result of the tax reform. We show that a deficit-financed tax reform improves remarkably growth and welfare. This result arises when the economy faces a dynamic Laffer curve: a substitution of debt for taxes today increases the growth rate of output, thereby expanding the tax base sufficiently in the long run to generate larger total tax revenues even at the lower tax rate.

Furthermore, we find that a deficit-financed tax reform is more difficult for those economies with a low value for the weight of pollution in the utility function or a low value for the externality effect of physical capital in the pollution function.

In the following section the model is described. In section 3 we study the optimal tax rates on consumption, income and pollution when the government is not issuing any debt and balances its budget period-by-period. In section 4 we characterize the tax reforms that improve both growth and welfare. Section 5 concludes.

2. THE MODEL

2.1. Households

We consider an economy populated with an infinitely-lived, representative household. The household obtains income from capital renting. Households' utility depends positively on consumption and negatively on aggregate pollution:

$$U(C_t, P_t) = \begin{cases} \dfrac{\left(C_t P_t^{-\eta}\right)^{1-\sigma} - 1}{1-\sigma} & \text{for } \sigma > 0,\ \sigma \neq 1 \\ \ln C_t - \eta \ln P_t & \text{for } \sigma \neq 1 \end{cases}$$

where C_t, P_t are the levels of consumption and pollution respectively, σ is the parameter for the intertemporal elasticity of substitution and η the weight of pollution in utility. Utility is increasing in consumption at a decreasing rate, $U_C > 0, U_{CC} < 0$, while it is decreasing in aggregate pollution $U_P < 0$. Additionally, $sign(U_{PP}) \geq (\leq)\ 0 \Leftrightarrow \sigma \leq (\geq)(1+\eta)/\eta$.

Note that P_t is not a choice variable to individual agents. Although each agent cannot influence P_t with his individual decision, the aggregate P_t is endogenous. It is assumed that aggregate pollution depends positively, in a non-linear fashion, on the aggregate physical capital level. That is, $P_t = g(K_t)$, with g'>0.

The household chooses the levels for C_t, K_{t+1} (physical capital) and B_{t+1} (bonds) that solve the following problem:

$$\underset{\{C_t, K_{t+1}, B_{t+1}\}}{Max} \sum_{t=0}^{\infty} \beta^t\, U(C_t, P_t) \tag{1}$$

subject to

$$K_{t+1} = (1-\tau_K) r_t K_t + T_t - (1+\tau_C) C_t + (1-\delta) K_t - \frac{B_{t+1}}{R_t} + B_t \tag{2}$$

$$K_0, B_0 \quad \text{given,}$$

where τ_K and τ_C are the tax rates on capital income and consumption, r_t is the return on capital renting, T_t are lump-sum transfers received from government, B_t is the stock of public debt owned by the household at period *t*, R_t is the interest rate on debt, and δ is the rate of physical capital depreciation.

We assume that the pollution function is:

$$P_t = K_t^{\chi}, \quad \text{with } \chi>0, \tag{3}$$

where χ is the elasticity of pollution with respect to capital. Finally, the restriction $\chi\eta < 1$ is imposed in order to guarantee that the utility function is bounded.

2.2. Firms

Firms rent capital from households at the interest rate r_t and must pay a pollution tax τ_P on the level of capital. The profit function in every period is given by

$$\pi_t = Y_t - r_t K_t - \tau_P K_t \ , \tag{4}$$

and we assume that the production function is linear in the only input which is physical capital, $Y_t = A\,K_t$.

The firm chooses the path for K_t to maximize its profit flow (5), and takes as given the market price of inputs. The equilibrium real interest rate paid to households is:

$$r_t = A - \tau_P \ . \tag{5}$$

2.3. Government

The government raises taxes (over consumption, income and pollution) and issues public debt. Public revenues are redistributed to households by lump-sum transfers.

The government budget constraint is as follows:

$$\frac{B_{t+1}}{R_t} + \tau_K r_t K_t + \tau_P K_t + \tau_C C_t = T_t + B_t \ . \qquad (6)$$

The government's ability to issue debt is constrained by the terminal condition:

$$\lim_{T\to\infty}\left[\frac{B_{T+1}/R_T}{\prod_{s=0}^{T-1} R_s}\right] = 0 \ , \qquad (7)$$

which guarantees that the period by period constraint (7) can be combined into an infinite horizon, present value budget constraint.

2.4. The Market Solution

Definition. *A competitive equilibrium for this economy is a set of allocations* $\{C_t, K_t, B_t\}$ *and a price system* $\{r_t, R_t\}$ *such that, taking the price system and fiscal policy* $\{\tau_K, \tau_P, \tau_C, T_t\}$ *as given,* $\{C_t, K_{t+1}, B_{t+1}\}$ *maximizes households' utility (1), subject to (2), the path* $\{K_t\}$ *satisfies the firms' profit maximization conditions, and* $\{C_t, K_{t+1}\}$ *satisfy the aggregate resources constraint.*

Using the first order conditions for consumers and firms, and imposing the equilibrium condition for the goods market, the aggregate resources constraint is

$$K_{t+1} = AK_t - C_t + (1-\delta)K_t \ . \qquad (8)$$

By substitution of the real interest rate into the consumer's intertemporal substitution condition, and imposing the condition for balanced growth rate ($K_{t+1}/K_t = C_{t+1}/C_t$), the equation for the market growth rate (g_M) is derived:

$$g_M = \left[\beta\, R(\Phi)\right]^{1/(\sigma+\chi\eta(1-\sigma))} \ , \qquad (9)$$

where $R(\Phi) = \Phi + 1 - \delta$, is the return on bonds, and $\Phi = (1-\tau_K)(A-\tau_P)$. From now, we assume that $\sigma + \chi\eta(1-\sigma) > 0$ to guarantee a positive elasticity of the growth rate with respect to the return on bonds.

2.5. The Planner Solution

In contrast to a market solution, the central planner maximizes the utility of the representative economic agent and takes pollution into account. The central planner maximizes lifetime utility by choosing time paths for $\{C_t, K_{t+1}\}$ subject to the aggregate resources constraint (8).

The rate of growth for the planner solution (g_P) is given by the following expression:

$$g_P = \left[\beta\left(A+1-\delta-\chi\eta\frac{C_{t+1}}{K_{t+1}}\right)\right]^{1/(\sigma+\chi\eta(1-\sigma))} . \qquad (10)$$

Using (8), the value for $\frac{C_t}{K_t}$ in the planner solution is derived:

$$g_P = A+1-\delta-\frac{C_t}{K_t} \Rightarrow \left(\frac{C_t}{K_t}\right)_P = A+1-\delta-g_P . \qquad (11)$$

Taking (10) and (11), the planner growth is computed numerically from:

$$g_P = \left[\beta\left(A+1-\delta-\chi\eta(A+1-\delta-g_P)\right)\right]^{1/(\sigma+\chi\eta(1-\sigma))} , \qquad (11)$$

which depends on parameters $A, \delta, \chi, \eta,$ and σ.

3. OPTIMAL POLICY

Hettich (2000) studied a model similar to ours, but he did not include government debt. He proved that consumption tax is a lump-sum tax, and that there are a continuum of (τ_P, τ_K)-pairs yielding the same rate of growth for the economy.

These results hold in our model. The proof is direct. Let's assume a given value for $\Phi = \overline{\Phi} > 0.$ First, from equation (9), the (τ_P, τ_K)-pairs verifying $(1-\tau_K)(A-\tau_P) = \overline{\Phi}$ yield the same market growth. Second, from the resources constraint:

$C_t = K_0\left[A+(1-\delta)-g_M(\Phi)\right]\left[g_M(\Phi)\right]^t$. Since the market growth and consumption do not depend on consumption tax, it can be defined as a lump-sum tax.

The following propositions derive additional results of the model.

Proposition 1. *The (τ_P, τ_K)-pairs yielding the same value of Φ also yield the same levels for tax revenues and welfare.*

Proof. First, welfare depends on consumption and pollution, both of which are functions of Φ. It has already been proved that C_t is a function of Φ. On the other hand, using (3), $P_t = K_t^{\chi} = K_0^{\chi}[g_M(\Phi)]^{\chi t}$. Therefore, C_t and P_t do not change unless Φ does (ceteris paribus).

Second, taxes revenues (Ψ_t) are obtained from taxes on pollution, capital income and consumption:

$$\Psi_t = \tau_P K_t + \tau_K r_t K_t + \tau_C C_t \,. \tag{13}$$

Using the expression for C_t as a function of $g_M(\Phi)$ and (5), the expression (13) can be written as:

$$\Psi_t = K_0 \cdot \Psi(\Phi, \tau_C) \cdot \left[g_M(\Phi)\right]^t \,. \tag{14}$$

where $\Psi(\Phi,\tau_C) = \left[A - \Phi + \tau_C\left(A + 1 - \delta - g_M(\Phi)\right)\right]$. Assuming a constant value for τ_C, this equation guarantees that tax revenues hold constant for a given Φ, as long as neither growth rate $\left(g_M(\Phi)\right)$ or detrended taxes $\left(\Psi(\Phi,\tau_C)\right)$ change.

Definition. *Iso-revenue curve is the locus of points (τ_P, τ_K) along which tax revenues are constant and τ_C is held constant.*

The properties characterizing the iso-revenue curve are the following:

1. *Each iso-revenue curve is associated with a level of Φ.*
2. *Growth and welfare keep constant along a given iso-revenue curve.*

3. *Each iso-revenue curve is concave and decreasing in* τ_P: Taking derivatives in $\Phi = (1-\tau_K)(A-\tau_P)$ and assuming Φ constant

$$\frac{\partial \tau_K}{\partial \tau_P} = -\frac{(1-\tau_K)}{(A-\tau_P)} < 0,$$

and

$$\frac{\partial^2 \tau_K}{\partial \tau_P^2} = -\frac{(1-\tau_K)}{(A-\tau_P)^2} < 0.$$

4. *Curves nearer to (0,0) are obtained from higher values of* Φ: When $\chi\eta < 1$ (condition for bounded utility), $\sigma + \chi\eta(1-\sigma) > 0$, so from (9): $\left(\partial g_M(\Phi)/\partial\Phi\right) > 0$ and from (14): $\left(\partial\Psi(\Phi,\tau_C)/\partial\Phi\right) < 0$. Therefore, curves nearer to (0,0) yield higher growth and lower detrended tax revenues.

5. *Welfare is maximized for the iso-revenue curve corresponding to* Φ^*, where:

$$\Phi^* = \chi\eta(A+1-\delta-g_P). \tag{15}$$

This is obtained comparing the market growth (g_M) and the planner growth (g_P) (equations (9) and (12)). In particular, two extreme points of the optimal iso-revenue curve can be derived: a) if $\tau_K^* = 0 \Rightarrow \tau_P^* = \chi\eta(A+1-\delta-g_P)$, and b) if $\tau_P^* = 0 \Rightarrow \tau_K^* = (\chi\eta/A)(A+1-\delta-g_P)$. In the case a), the first-best solution is obtained imposing a pollution tax equal to the optimal marginal damage of pollution. In the second, setting the income tax equal to the optimal marginal damage of pollution divided by the marginal product of capital. The latter is necessary to correct for the tax-base differences between a capital income tax and a pollution tax.

Figure 1 shows two iso-revenue curves. All (τ_P, τ_K)-pairs along the curve $\Psi^*(\Phi^*)$ satisfy (15). That is, all of these taxes mix are first-best optimal and $\Psi^*(\Phi^*)$ yield the optimal public transfers level. All (τ_P, τ_K)-pairs along the curve $\Psi'(\Phi')$ allow financing a higher detrended public spending. Welfare associated to tax revenues $\Psi'(\Phi')$ is lower than the one corresponding to the level $\Psi^*(\Phi^*)$.

[INSERT FIGURE 1]

In this framework, if the path of\ government spending is given by $\{T_t\}_0^\infty = \left\{\Psi'(\Phi', \tau_C)\left[g_M^{'}(\Phi')\right]^t\right\}_0^\infty$, and the government increases pollution tax and reduces income tax in such a way that issuing debt is not necessary, this tax reform keeps growth, pollution and welfare constant. However, it is possible to design an alternative fiscal policy which ensures the same level of spending and yields a higher welfare. This alternative consist of substituting debt for taxes. The next section analyzes this possibility.

4. A WELFARE-GROWTH IMPROVING TAX REFORM

This section studies alternative ways of financing a reduction in income tax rate. We take as reference an economy in which the government balances its budget each period, so that debt has never been issued ($B_t = 0, \forall t$). Therefore, the predetermined level of government expenditure (given by the transfers path $\{T_{t,0}\}_{t=0}^\infty$) is only financed by taxes on consumption, capital income and pollution, given by $\tau_K = \tau_{K,0}, \tau_P = \tau_{P,0}, \tau_C = \tau_{C,0}$.

Hence, the government budget constraint is given by $T_{t,0} = \Psi_{t,0} = K_0 \Psi_0(\Phi_0, \tau_{C,0})\left[g_M^0(\Phi_0)\right]^t$, $\forall t = 0,1,2,...$ (with $\Phi_0 = (A - \tau_{P,0})(1 - \tau_{K,0})$). The economy will stay on its balanced growth path growing over time at a constant rate $g_M^0(\Phi_0)$.

Let us suppose that the government considers a permanent reduction in the tax rate on income (τ_K) keeping unchanged both the other tax rates and the initial transfers path $\{T_{t,0}\}_{t=0}^{\infty}$. In a non-monetary economy, the government will need issuing debt which might hopefully be retired over time. The cut in τ_K increases Φ and, consequently, increases the long-run growth rate of the economy, thereby expanding the tax base and leading to higher revenues at some point. A reduction in τ_K is feasible if the subsequent increase in the tax base allows for the government budget constraint to hold in a present value sense. That would mean that the bigger deficit in the initial periods after the policy change can be repaid by achieving later on a fiscal surplus higher in present value than the one under the initial policy. That will allow for eventually retiring the initially issued debt, with no need to introduce tax hikes at any point in time.[1]

On the contrary, fiscal reforms that substitute debt for consumption tax rate (τ_C), keeping constant the other tax rates, are not feasible because the consumption tax rate does not affect the growth rate. This implies that the future tax base will not increase and the implied debt path will never be retired.

As an illustration of a deficit-financed reduction in τ_K, let us suppose that at t=0, the government implements a new capital income tax rate, $\tau_{K,1}$, with $\tau_{K,1} < \tau_{K,0}$, keeping constant $\tau_{P,0}, \tau_{C,0}$. This implies that $\Phi_1 > \Phi_0$. Let us denote by $\Psi_{t,1}$ the tax revenues under the reduced capital income tax in the period t:

$$\Psi_{t,1} = \tau_{P,0} K_{t,1} + \tau_{K,1} r_{t,1} K_{t,1} + \tau_{C,0} C_{t,1} ,$$

or, equivalently,

$$\Psi_{t,1} = K_0 \cdot \Psi_1\left(\Phi_1, \tau_{C,0}\right) \cdot \left[g_M^1\left(\Phi_1\right)\right]^t, \text{ for } t\text{=0,1,2,...}$$

where $\Psi_1(\Phi_1, \tau_{C,0}) = \left[A - \Phi_1 + \tau_{C,0}\left(A + 1 - \delta - g_M^1(\Phi_1)\right)\right]$. Hence, from (6) the government budget constraint is

$$\frac{B_{t+1}}{R_1} + \Psi_{t,1} = \Psi_{t,0} + B_t, \text{ with } B_0 = 0,\ t = 0,1,2,... \tag{16}$$

where we maintain the same expenditure path as before the tax cut, $T_{t,0} = \Psi_{t,0}$ $(\forall t)$ and R_1 is the return on public debt after the tax reform.

Using the transversality condition (7) together with the initial condition B_0=0, (16) can be solve further as

$$\sum_{t=0}^{\infty} \frac{\Psi_{t,1} - \Psi_{t,1}}{R_1^t} \geq 0,$$

or, equivalently,

$$\frac{\Psi_1(\Phi_1, \tau_{C,0})}{1 - g_M^1(\Phi_1)/R_1(\Phi_1)} - \frac{\Psi_0(\Phi_0, \tau_{C,0})}{1 - g_M^0(\Phi_0)/R_1(\Phi_1)} \geq 0. \tag{17}$$

This inequality characterizes the time paths for revenues, expenditures and interest rates which are consistent with a feasible tax reduction.

We use figure 2 to explain this fiscal reform (assuming that the parameter values guarantee that there is a non-zero feasible tax cut[2]). The *AB*-curve shows the $\left(\tau_P, \tau_K\right)$-pairs yielding the same tax revenues that the initial fiscal policy ($\left\{\tau_{P,0}, \tau_{K,0}, \tau_{C,0}\right\}$, placed in *H*[3]). Any reduction in the capital income tax rate inside the shaded area from *H* towards the point H_1 (located at the *A'B'*-curve) is feasible and (17) holds as an strict inequality (this means that the debt initially issued is eventually retired, and the government runs a present value surplus that could be returned as additional transfers to consumers). A tax cut from *H* to H_1 implies that (17) holds as an equality. A higher tax cut would not be feasible, that is, (17) would not hold.

Since the *A'B'*-curve is associated to $\Phi = \Phi_1$, all points along this curve (including H_1) yield the same growth and welfare, higher than the growth and welfare for the points belonging to the *AB*-curve (corresponding to $\Phi = \Phi_0$). The *A'B'*-curve shows the maximum feasible tax cuts from any point along the *AB*-curve and the shaded region shows all the feasible fiscal reforms. That is, for example, any fiscal reform from *H* to *A'* or from *H* to H_1 or from *H* to *B'* is feasible. In addition, all of them share the same welfare improvement. This implies that a green tax reform (the economy moves from *H* to a point in *A'B'* between H_1 and *B'*) is equivalent to fiscal reforms that reduce the pollution tax rate (the economy moves from *H* to a point in *A'B'* between H_1 and *A'*). This result is due to the model linearity.

[INSERT FIGURE 2]

The next section discusses numerically the feasibility of the designed tax reform under a benchmark parameter vector. Also summarizes the results of the sensitivity analysis for the most relevant parameters.

4.1. Numerical Results

It is not possible to determine analytically the range of parameter values for which (17) is satisfied. However, it is possible to evaluate (17) numerically when specific values are chosen for the parameters and to see how the function changes as one of its arguments varies while the others are held constant.

We are also interested on measuring welfare effects associated to reducing τ_K, keeping constant τ_P, τ_C and transfers (T_t). It amounts the change in consumption that an individual would require each period to be as well off under the initial situation (without debt) as under the new tax structure. The result is expressed as a percentage on output. Hence, a positive value for this measure corresponds to a rise in welfare.

A benchmark set of parameters is chosen, with one period in the model identified as one year in real time.

The rate of capital depreciation (δ) is set at 10%, the parameter of risk aversion (σ) is set at 1.5, the parameter $\mu = \chi\eta$ is chosen to be 0.5 and the consumption tax rate (τ_C) is assumed to be 0.1. The economy growth rate (*g*) is fixed at 2.0% and the after-tax real interest rate is set at 3.5%. To match these two statistics, *A*=0.18 and β=0.99. The public spending level is such that can be financed, among other possibilities, by a $(\tau_P, \tau_K) = (0, 0.247)$ or $(\tau_P, \tau_K) =$ (0.045, 0) or $(\tau_P, \tau_K) =$ (0.021, 0.15) that is, points *A* , *B* and *H* in figure 2 respectively. In all these cases, $\Phi_0 = 0.136$.

We assume that our economy is located at *H*. For this parameterization it is feasible to implement an income tax cut fiscal reform keeping constant the other taxes. The maximum feasible income tax cut leads the economy towards H_1=(0.021,0.016). Note that any fiscal reform which drives the economy towards a point on *A'B'*-curve is equivalent in terms of growth and welfare. In terms of the figure 2, the iso-revenue *A'B'*-curve is defined by the points *A'*=(0,0.129), *B'*=(0.023,0). In all these cases $\Phi_1 =$0.157, the economy grows at 3.7% and the welfare improvement is 5.3%. Thus, if the government wants to remove completely the capital income tax rate (from *H* to *B'*), it will need to increase the pollution tax from 2.1% to 2.3%, increasing the social welfare. On the other hand, if the government is not allowed to issue debt (from *H* to *B*), then it must increase the pollution tax rate from 2.1% to 4.5% and welfare keeps unchanged.

Needless to say, there are parameterizations for which no fiscal reform is feasible, that is, the shaded region (or feasible region) is empty. There are also parameterizations for which the frontier of the feasible region is nearer to (0,0) than the optimal iso-revenue curve ($\Psi^*(\Phi^*)$; in this case, the tax reform that yields the largest welfare improvement is any point along the optimal iso-revenue curve.

Next, we discuss how the feasible region depends on μ (which has not been previously calibrated in the RBC literature) and σ (with a wide range of calibrated values in the literature). The first, $\mu\ (=\chi\eta)$ measures the influence of the pollution in our economy and the second, σ, measures the inverse of the intertemporal elasticity of substitution.

We obtain that the higher the value of μ, the wider the shaded region in figure 2. When μ is very low, the fiscal reform is not feasible. It would be the case for economies with a low weight of pollution in the utility function and/or a low externality effect of physical capital in the pollution function. The polluting-motivated revenues are very low to compensate the reduction in the capital income tax. As a consequence, the deficit financing of the rate cut is more difficult. On the contrary, the larger the desutility of pollution and/or the polluting externality of capital, the more likely the fiscal experiment.

The figure 3 shows the sensitivity analysis for μ. Under the benchmark setup and $\tau_{C,0}=0.1$, $\tau_{K,0}=0.15$ and $\tau_{P,0}=\tau_P^*=\chi\eta(A+1-\delta-g_P)$ - where g_P is given by (12),- we compute first the largest feasible cut in the income tax rate and, second, the feasible cut yielding the largest welfare improvement for each $\mu\in$ (0,0.87).[4] In the figure, it can be seen that for μ <0.12, no tax cut is feasible (the shaded region in figure 2 is empty). For μ >0.53, it is feasible not only removing the income tax but even imposing a subsidy on income. However, the welfare gain is lower for $\tau_{K,1}$<0 than for $\tau_{K,1}$=0, because this latter fiscal reform places the economy along the optimal iso-revenue curve. In this case, the largest tax cut does not yield the largest welfare improvement (the frontier of the feasible region is nearer to (0,0) than the optimal iso-revenue curve). In this economy, the government can reach a first best fiscal policy (this tax reform places the economy along the optimal iso-revenue curve.).

[INSERT FIGURE 3]

Another interesting analysis is the one related to the parameter σ. Equation (9) indicates that the elasticity of the growth rate (g_M) with respect to the after-tax return on capital *R* is $1/\left(\sigma(1-\chi\eta)+\chi\eta\right)$. Thus, the size of the growth effect decreases as a function of σ, since $\chi\eta<1$. We obtain that the higher the value of $1/\sigma$, the wider the shaded region in figure 2. On the contrary, those economies with a small elasticity of substitution (that is, with a very smooth consumption path) have few (or null) possibilities to implement the kind of tax reform proposed in the paper.

The figure 4 shows the sensitivity analysis for $\sigma \in$ (1,6). The analysis setup is similar to μ. In the figure, it can be seen that for σ >5.25, no tax cut is feasible (the shaded region in figure 2 is empty). For σ <1.15, it is feasible not only removing the income tax but imposing a subsidy on income. As we discussed before, in this case it is preferable (in terms of welfare) removing the income tax rather than imposing an income subsidy (the frontier of the feasible region is nearer to (0,0) than the optimal iso-revenue curve).

[INSERT FIGURE 4]

This sensitivity analysis has been extended to the remaining structural parameters (of technology and preferences)[5] and we have also verified that a dynamic Laffer curve exists for a wide range of parameter values, in particular for those usually considered in the literature of real business cycles.

5. CONCLUSIONES

We use a simple AK model with negative environmental externality in utility function and without abatement activities, where the government has to finance a non-optimal level of spending. In this environment, two findings are obtained:

i) under a period-by-period balanced budget, a revenue-neutral green tax reform has not any effect on pollution, growth or welfare;

ii) allowing the government to substitute debt for distortionary taxes, a continuum of fiscal reforms improve growth and welfare *if such reforms are feasible*. Note that a tax reform towards a less distorting fiscal system will increase growth thereby increasing the tax base. Such tax reform is feasible if the subsequent increase in the tax base allows for the government budget constraint to hold in a present value sense.

We show that there are parameterizations for which the fiscal reform that leads to the highest initial deficit does not yield the largest welfare improvement. In this economy, the government could implement a first best tax mix.

Because of the model linearity, there exist green and non-green deficit-financed tax reforms that yield the same welfare improvements. However, assuming abatement activities would break the equivalence between green and non-green tax reforms. This issue will be studied in a future research.

FOOTNOTES

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1 A similar analysis, in an endogenous growth model without pollution, can be found in Ireland (1994) and Novales and Ruiz (2002).

2 In the next sub-section a numerical example is presented.

3 We assume that the government revenues for an economy located at H are higher than those obtained under the optimal fiscal taxes ($\Psi^*(\Phi^*)$).

4 For μ >0.87 and the remaining parameters at their benchmark values, the long run growth rate is negative.

5 It is available upon request.

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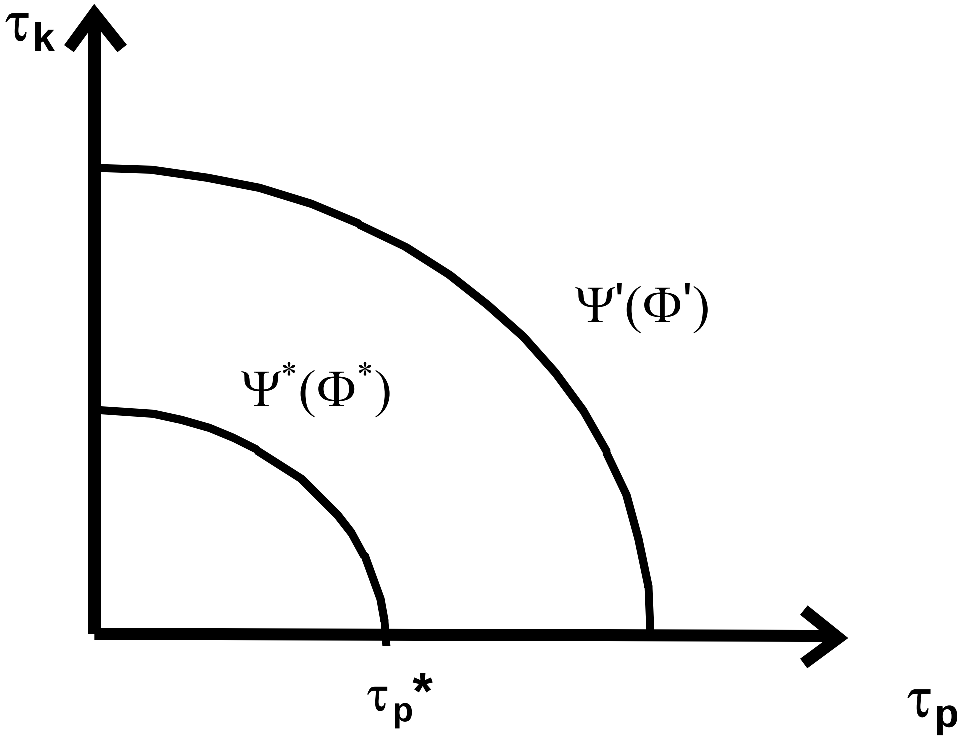

Figure 1. Iso-revenue Curves

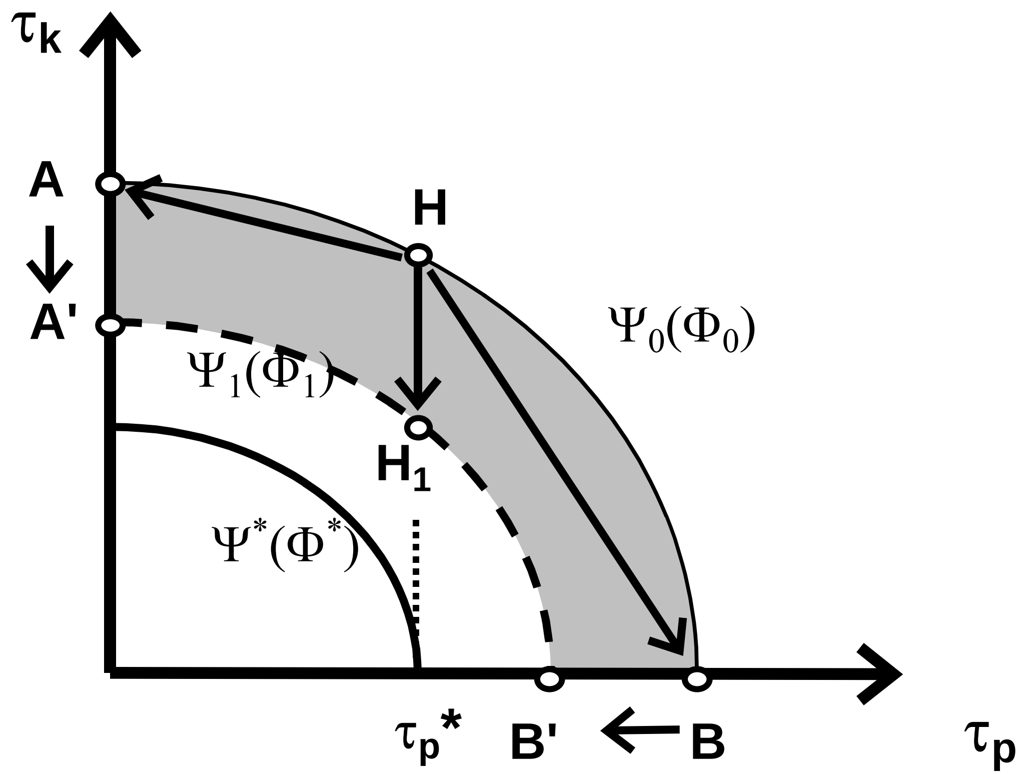

Figure 2. Welfare-growth improving tax reform

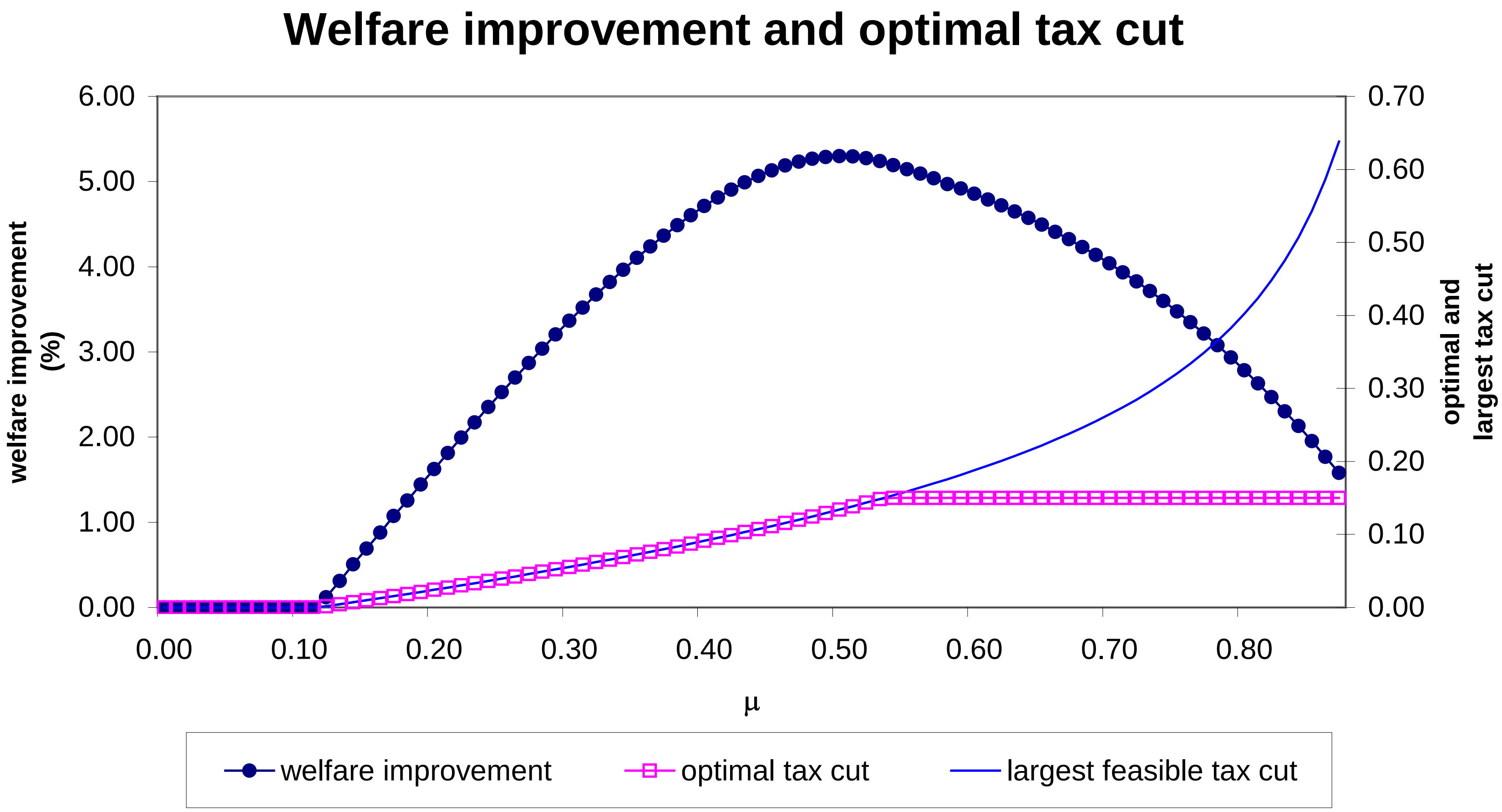
Welfare improvement and optimal tax cut
welfare improvement (%)
optimal and largest tax cut
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
μ
welfare improvement
optimal tax cut
largest feasible tax cut

Figure 3

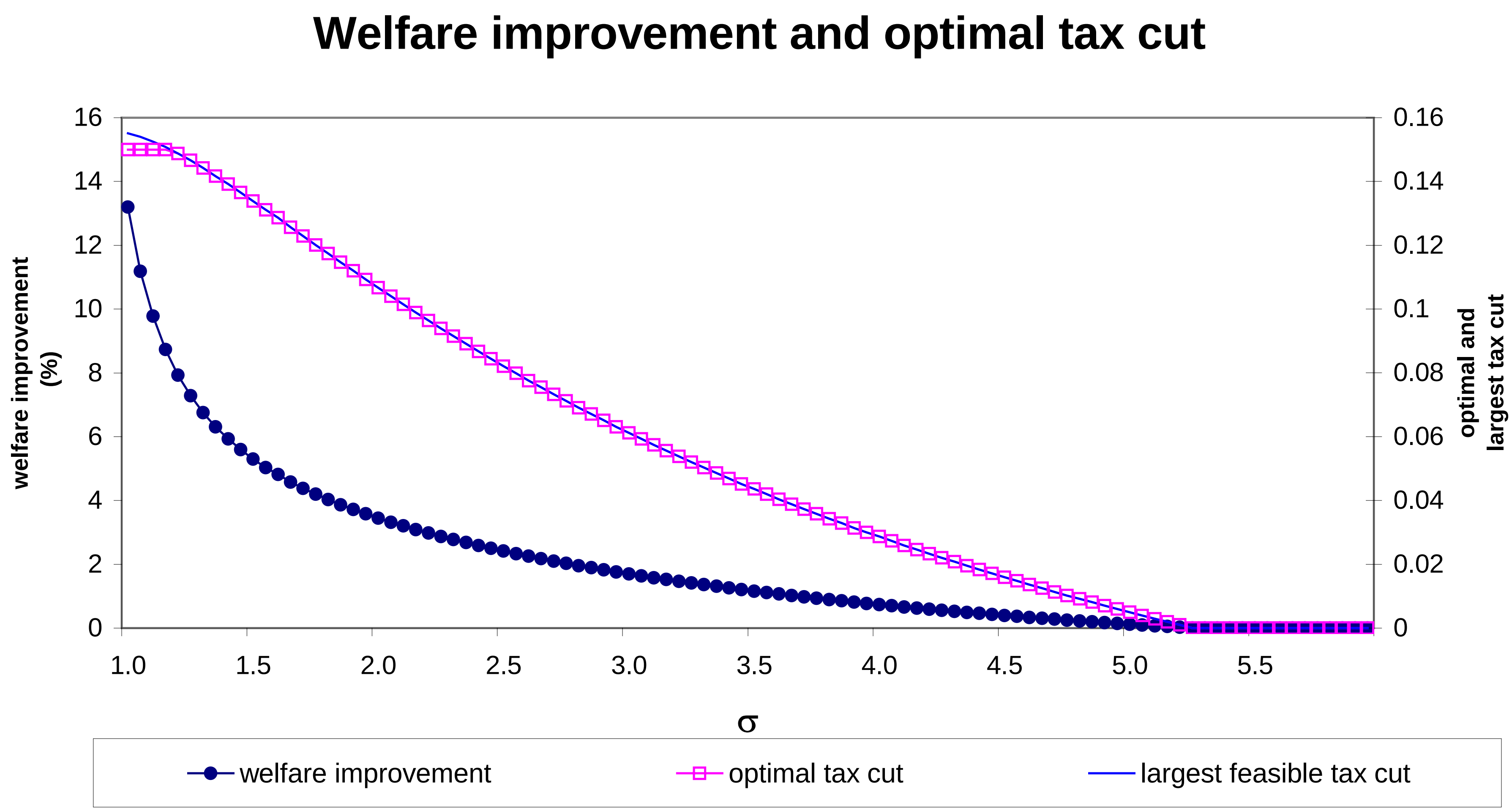
Welfare improvement and optimal tax cut
welfare improvement (%)
optimal and largest tax cut
16
14
12
10
8
6
4
2
0
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
σ
welfare improvement
optimal tax cut
largest feasible tax cut

Figure 4