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Tax Reform and Public Spending Trade-offs in an Endogenous Growth Model with Environmental Externality

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Summary

This paper analyzes the trade-offs between fiscal policy reform and public expenses structures within a two-sector endogenous growth model with an environmental externality. Transitional dynamics, balanced growth path and welfare cost of alternative policy are computed. We show that taxes structure change leads to a lower welfare cost.

Keywords: Endogenous growth, human capital, environmental externality, tax reform, transitional dynamics, welfare

JEL: E62, I21, H22, Q28, O41, D62

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1 Introduction

The relative average size of public spending in GNP for the OCDE economies has increased from 28,9% in 1965 to 41,7 in 1998. For the economies in the European Community, the public spending-GNP ratio has increased from 36,1% to 47,8% in the same period of time. Likewise, the evolution of the relative importance of the di®erent types of taxes on total public revenues shows a clear tendency towards increases in income taxes. In the same time environmental policy becomes in the ¯rst line of sight for the majority of government.

Recent macroeconomic theory has made progress in analyzing the dynamics e®ects of taxes, particularly within the framework of endogenous growth model. Barro (1990) looks at the government spending and income taxation in a model where government activity enters directly into production as a public intermediate input. The analysis of ¯scal policies in endogenous growth models with human capital accumulation is relatively recent [e.g. King and Rebelo (1990), Lucas(1990), Devereux and Love (1996), Stockey and Rebelo (1996), Ortiguera (1998)]. These studies have basically focused on the relationship between tax rates and long-run growth rates.

In a Uzawa-Lucas setup augmented with an explicit treatment of the environment, Gradus and Smulders (1993) ¯nd that the optimal growth rate is independent from environmental care. Only by assuming that pollution also negatively a®ects the e±ciency in the human-capital sector, did they detect positive growth e®ects. Oueslati (2002) shows that in Uzawa-Luas model with leisure a higher pollution tax might boost long-run economic growth even without assuming direct positive productivity e®ects of a cleaner environment.

Whereas most endogenous growth models dealing with environmental concerns restrict the analysis to the steady state, little has been said so far on the short-run e®ects of taxation. Van der Ploeg and Ligthart (1994), Bovenberg and Smulders (1996), Vellinga (2000) and Oueslati (2002) are the few exceptions in the literature. Without taking the environmental externality into account, Mulligan and Sala-i-Martin (1993), Devereux and Love (1994) and Lardon-de-Guevara and al.(1997) investigate the transitional dynamics within similar models.

This paper studies the e®ects of both public spending policy and tax reform on welfare within a two sector model of endogenous growth based on the joint accumulation of physical and human capital. Both transitional dynamics and balanced growth path are computed.

The remainder of the paper is organized as follows. In section 2 the general model is laid out and market solution is derived. Section 3 proposes a numerical exercise: we calibrate the model at the steady state, compute the transitional dynamics and comment the short-run dynamics. Section 4 computes welfare costs of public policy choice. Section 5, summarizes the main findings.

2 The model

We consider an economy populated with an infinitely-lived representative household. The household owns the stock of physical capital in the economy, K_t, and is endowed with a (normalized) unit time. The time endowment can be allocated between work (remunerated at the current competitive wage rate) and schooling. The pollution causes a negative environmental externality as a side product. Pollution is assumed to affect individuals' utility.

2.1 Preferences, technology and pollution

The behavior of the rational household is guided by the maximization of the discounted lifetime utility

$$W_0 = \sum_{t=0}^{\infty} \beta^t u(C_t; P_t) \tag{1}$$

where

$$u(C_t; P_t) = \log C_t - \phi \log P_t \tag{2}$$

C_t is consumption, $0 < \beta < 1$ is the discount factor and P_t is the net pollution flow. The parameter ϕ represents the weight of pollution in utility. The consumer budget constraint can be written as follows :

$$K_t = \left[1 + \left(1 - \tau_t^K\right) r_t - \delta_K\right] K_{t-1} + \left(1 - \tau_t^H\right) w_t u_t H_{t-1} - C_t \tag{3}$$

where r_t is the return to physical capital and w_t is the gross wage rate per effective unit of human capital $u_t H_{t-1}$. u_t is the supply of working time. δ_K denotes the rate of depreciation for physical capital. τ_t^K and τ_t^H are respectively a tax on capital income and a wage tax

The representative agent can increase his human capital stock H_t, by devoting time to schooling. We assume that this activity takes place outside the market, and new human capital can only be obtained by spending time. Thus, the law of motion for human capital is given by the constraint

$$H_t = [1 + B(1 - u_t) - \delta_H] H_{t-1} + E_t \tag{4}$$

where B is the marginal productivity of schooling time $(1 - u_t)$, δ_H denotes the rate of human capital depreciation and E_t is public education expenses.

The physical capital used in production is the source of the pollution flow P. This flow can be reduced by means of private abatement activities D which in turn consume a part of output, in line with the flow resource constraint. The net pollution function has the form:

$$P_t = Y_t / D_t \tag{5}$$

2.2 Firms

The economy consists of a large number of identical and competitive firms. They rent capital and hire effective labor from the households at the interest rate r and the wage rate w respectively: They use the following constant-returns Cobb-Douglas technology

$$Y_t = A K_{t-1}^{\alpha} (u_t H_{t-1})^{1-\alpha} \tag{6}$$

where $A > 0$ and $0 < \alpha < 1$.

Firms are assumed to maximize their market value, which is equal to the appropriately discounted sum of profits flows, the later is given by

$$\pi_t = Y_t - r_t K_{t-1} - w_t u_t H_{t-1} \tag{7}$$

Profits maximization implies that in equilibrium, firms pay each production factor at its marginal productivity.

$$r_t = \alpha \frac{Y_t}{K_{t-1}} \tag{8}$$

$$w_t = (1 - \alpha) \frac{Y_t}{u_t H_{t-1}} \tag{9}$$

2.3 Government

We suppose that government revenue Z_t is used both as public abatement activity (D_t) and education spending (E_t). The government budget constraint implies that in every period, we have :

$$Z_t = \tau_t^K r_t K_t + \tau_t^H w_t H_t = D_t + E_t \tag{10}$$

Let

$$D_t = \theta Z_t \text{ and } E_t = (1 - \theta) Z_t \qquad 0 \leq \theta \leq 1 \tag{11}$$

The market clearing condition for the goods market is

$$Y_t = C_t + K_t - (1 - \delta_K) K_{t-1} + Z_t \tag{12}$$

2.4 The market solution

Definition 1 A competitive equilibrium for this economy consists of the consequences $\left\{C_t; Y_t; K_t; H_t; u_t; Z_t; r_t; w_t; \tau_t^K; \tau_t^K; P_t\right\}$ for $t = 1; 2; 3 \ldots$ and for $0 \leq \theta \leq 1$, that satisfy the following conditions.

(a) Household utility maximization :

Maximize (1)

subject (3), (4) and (5)

$\lim_{t \to \infty} \beta^{-t} \lambda_t K_t = \lim_{t \to \infty} \beta^{-t} q_t H_t = 0$

H_0 and K_0 given.

(b) Profit maximization

(c) Government budget constraint (15)

(d) Market clearing : $C_t + Z_t + K_t - K_{t-1}(1 - \delta_K) = Y_t$

The variables λ_t and q_t represent respectively the shadow prices of physical and human capital.

So as to characterize the competitive equilibrium, let us focus on the different trade-offs faced by the household. After eliminating the shadow prices for physical and human capital, the first order conditions for the household problem write

$$\frac{C_{t+1}}{C_t} = \beta \left[1 + \left(1 - \tau_{t+1}^K \right) r_{t+1} - \delta_K \right] \tag{13}$$

$$\frac{C_{t+1}}{C_t} = \beta \frac{1 - \tau^H_{t+1}}{1 - \tau^H_t} \frac{w_{t+1}}{w_t} [1 + B - \delta_H] \tag{14}$$

Equation (13) and (14) are the Euler conditions determining the optimal accumulation of physical and human capital. It is obvious that environmental tax affects only the intertemporal incentive to invest in physical capital, as described by equation (13).

These conditions, along with equations (2), (3), (4), (8), (9), (10) and (11) constitute a dynamical system in C, D, u, K and H which, together with the transversality conditions[1] and initial $K(0)$ and $H(0)$, fully describe the dynamic behavior of the economy along an interior equilibrium.

3 The balanced growth path

In this section we will focus on the dynamic properties of the balanced growth path.

Definition 2 A balanced growth path (or steady state) is an allocation $\{C_t, Z_t, u_t, K_t, H_t, P_t, T_t\}$, a price system $\{r_t, w_t\}$ and a taxes τ^K and τ^H satisfying Definition 1, and such that for some initial conditions $K(0) = K_0$ and $H(0) = H_0$, the paths $\{C_t, Z_t, K_t, H_t\}$ grow at the constant rate g, and u_t and P_t remain constant.

For analytical convenience we use the following transformed variables: $h_t = H_t/K_t$, $c_t = C_t/K_{t-1}$, $y_t = Y_t/K_{t-1}$, $z_t = Z_t/K_{t-1}$ and $g_t = K_t/K_{t-1}$.

Using this change of variables, we obtain the following dynamic system

$$r_t = \alpha y_t \tag{15}$$

$$w_t = (1 - \alpha) \frac{y_t}{u_t h_{t-1}} \tag{16}$$

$$g_t = 1 + y_t - d_t - c_t - \delta_K \tag{17}$$

$$g_t \frac{h_t}{h_{t-1}} = 1 + B(1 - u_t - l_t) - \delta_H \tag{18}$$

$$g_t \frac{c_{t+1}}{c_t} = \beta \left[1 + \left(1 - \tau^K_{t+1} \right) r_{t+1} - \delta_K \right] \tag{19}$$

[1] These conditions are standard and impose that the present discounted value of both capital stocks tends to zero at the infinity.

$$g_t \frac{c_{t+1}}{c_t} = \beta \left\{ \frac{1-\tau^H_{t+1}}{1-\tau^H_t} \frac{w_{t+1}}{w_t} \left[1 + B\left(1 - l_{t+1}\right) - \delta_H\right] \right\} \tag{20}$$

$$z_t = y_t \left[\alpha \tau^K_t + (1-\alpha)\tau^H_t\right] \tag{21}$$

Steady-state values c, z, u, P and g are obtained by eliminating the index t. From the linearization of the above system one can show that, independently of the size of taxes, the model displays a saddle path dynamic structure. Thus, unlike other models presented in the literature [Benhabib and Perli (1994), Bond and al. (1996), Xie (1994)] our model is unable to generate the indeterminacy phenomenon typical of distorted economies[2].

4 Numerical results

In this section we derive a full numerical solution for the model. For this calibration exercise we cannot really hope to be as precise as those who employ the same model without environmental externality, since we lack strong empirical evidence concerning the nature of the environmental preferences and pollution function. Nevertheless, to the greatest possible extent, we follow the recent literature. Prescott (1986) cites micro evidence for many of the key parameter values are not as robust as those of the standard model, we vary some parameters around our initial benchmark setting as a check on the sensitivity of the results.

4.1 Calibration

The parameter values require are discount factor β, technology parameters α, A, B, δ_K, and δ_H, tax rates (τ^K and τ^H) and abatement share in public expenses θ. We proceed by choosing parameters according to the arguments below to pin down a benchmark economy.

Following Prescott (1986) and other, we let the share of labour in final goods output $1-\alpha$ be 0.64. Let depreciation rates be the same across sectors and set equal $\delta_H = \delta_K = 0.01$[3]. Since the difference between A and B affects only the units in which the human to physical ratio is measured, we set $A = B$. Taking this as a proxy for the industrialized economies, the growth rate is 2 %.

[2] In Bond and al. (1996) indeterminacy emerges from the presence of taxes in a model with physical capital as an input in the educational sector. As we assume that physical capital is only productive in the output sector, the condition for general instability or indeterminacy is never satisfied. In Benhabib and Perli (1994) and Xie (1994) indeterminacy arises from knowledge spill-overs.

[3] See Barro and Sala-i-Martin (1995, p. 37)

For parameters tax, we consider a parameter ϕ which correspond to a combination between τ^H and τ^K with a constant public spending-GNP ratio $\gamma = Z/Y$. We let $\gamma^{BC} = 0.3$ which plausible for most developed countries. In the benchmark case, we suppose that $\tau^H = \tau^K$. Thus, we get $\phi^{BC} = 0.136$.

Table 1: Benchmark Parameter values

β	$= 0.99$	discount factor
g	$= 1.02$	growth rate
$\delta_K = \delta_H$	$= 0.01$	depreciation rate
α	$= 0.36$	physical capital share in product
ϕ	$= 0.136$	taxes combination parameter
$u =$	$= 0.28$	working time
$\gamma = Z/Y$	$= 0.3$	public spending share in product

Thus, we have chosen the following variables and parameters values β, g, δ_K, δ_H, α, ϕ, u, and γ. Values of the remaining parameters and variables are solution to the system (21)-(??). Benchmark case (BC) values are summarized in the table 2.

Table 2: Calibration Results in the BC

$\tau^K = \tau^H$	$= 0.3$	tax parameters
y	$= 0.1599$	final output per unit of physical capital stock
h	$= 30.7753$	H/K ratio
$A = B$	$= 0.0403$	production and human capital productivity
c/y	$= 0.5124$	Consumption share in product
θ^{BC}	$= 0.3703$	abatement share in public spending
P	$= 9.0021$	Pollution flow

With $\theta^{BC} = 0,3703$, we get education spending share in product $e/y = \left(1 - \theta^{BC}\right)\gamma^{BC} = 0,1889$ and abatement share in product $d/y = \theta^{BC}\gamma^{BC} = 0,1111$.

4.2 Balanced growth paths

The numerical solution for the balanced growth path is easily derived using a nonlinear equations solution procedure for the stationary representation for the system (15)-(21). We study now successively the effect on the steady state of both change in the structure of public spending, described by θ variation and variation in the government revenue, described by ϕ change.

4.2.1 Public spending structure

The ¯rst governmental policy consists in doing a change in its expenses structure. This policy is shown by the variation of µ. Thus, when µ is higher, abatement share is higher. This policy induce a decrease in the ratio h (production become less intensive in physical capital) and a decrease in the pollution °ow. The consumption share in the product remain constant (see table 1).

Table 1: Abatement share variation

	h	c=y	d=y	e=y	P
BC	30; 7753	0; 5124	0; 1111	0; 1889	9; 0021
$µ = 0;5 £ µ^{BC}$	29; 9131	0; 5124	0; 0555	0; 2445	18; 0041
$µ = 0;75 £ µ^{BC}$	30:3442	0; 5124	0; 0833	0; 2167	12; 0028
$µ = 1;5 £ µ^{BC}$	31; 6376	0; 5124	0; 1666	0; 1334	6; 0014

We note that all this e®ects are insensitive to ® and ³ (see table 2 and 3).

Table 2 : Sensibility to ®

	h	c=y	d=y	e=y	P
$µ = 0;5 £ µ^{BC}$	37; 4777	0; 5571	0; 0618	0; 2382	16; 192
$µ = 0;75 £ µ^{BC}$	37; 1068	0; 5571	0; 0926	0; 2074	10; 790
$µ = µ^{BC}$	37; 7360	0; 5571	0; 1235	0; 1765	8; 0962
$µ = 1;5 £ µ^{BC}$	38; 9944	0; 5571	0; 1853	0; 1147	5; 3975
for ® = 0; 3					

Table 3 : Sensibility to ³

	h	c=y	d=y	e=y	P
$µ = 0;5 £ µ^{BC}$	39; 1592	0; 4392	0; 0970	0; 3030	10; 3109
$µ = 0;75 £ µ^{BC}$	38; 2809	0; 4392	0; 1455	0; 2545	6; 8739
$µ = µ^{BC}$	39; 1592	0; 4392	0; 1940	0; 2060	5; 1555
$µ = 1;5 £ µ^{BC}$	40; 9158	0; 4392	0; 2910	0; 1090	3; 4370
for ³ = 0; 4					

4.2.2 Government revenue structure

We study now the e®ects of taxes reform on the steady state. We have calculated a parameter (Á), which measures the variation in $¿^{K}$ and $¿^{H}$ for a constant government revenue.

A public policy which favor the physical capital taxation, induce an intensive production in human capital and a fall in consumption share. We note too that pollution °ow rises.

Table 4 : Tax reform

	Taxes (%)		h	c=y	d=y	e=y	P
Á = 0:5Á^{BC}	¿^{K} = 17; 18	¿^{H} = 37; 18	23; 463	0; 4782	0; 111	0; 1889	10:664
Á = 0; 75Á^{BC}	¿^{K} = 24; 06	¿^{H} = 33; 34	26; 975	0; 496	0; 111	0; 1889	9:766
BC	¿^{K} = 30; 00	¿^{H} = 30; 00	30; 770	0; 512	0; 111	0; 1889	9:002
Á = 1:25Á^{BC}	¿^{K} = 39; 84	¿^{H} = 24; 46	39; 296	0; 5388	0; 111	0; 1889	7:736

All this e®ects are insensitive to ® and ³ (see table 5 and 6).

Table 5 : Sensitivity to ®

	Taxes (%)		h	c=y	d=y	e=y	P
Á = 0:5Á^{BC}	¿^{K} = 20:68	¿^{H} = 33:99	27:51	0:522	0:131	0:168	10:03
Á = Á^{BC}	¿^{K} = 36:01	¿^{H} = 27:43	37:73	0:557	0:123	0:176	8:09
Á = 1:5Á^{BC}	¿^{K} = 47:81	¿^{H} = 22:37	50:90	0:583	0:123	0:176	6:60
for ® = 0:30							

Table 6 : Sensitivity to ³

	Taxes (%)		h	c=y	d=y	e=y	P
Á = 0:5Á^{BC}	¿^{K} = 22:98	¿^{H} = 49:57	26:12	0:393	0:194	0:206	6:618
Á = Á^{BC}	¿^{K} = 40:00	¿^{H} = 40:00	39:15	0:439	0:194	0:206	5:155
Á = 1:5Á^{BC}	¿^{K} = 53:12	¿^{H} = 32:62	58:289	0:474	0:194	0:206	4:028
for ³ = 0:40							

4.3 Transitional dynamics

To compute the transitional dynamics we log-linearize the dynamic system (??)-(??) to make the equations approximately linear in the log-deviations from the steady state. After doing this, we solve the recursive equilibrium law of motion via the method of undetermined coe±cients. We compute the transitional dynamics associate with to kind of public policy.

4.3.1 Spending shares change

The simulation of the transitional dynamics starts in period 0, where the government suddenly changes the spending shares (µ). This public policy shock induces an instantaneous reaction of all economic variables. We then observe di®erent impacts on the variables, which leave their initial level at BC and reach at di®erent rates their new level.

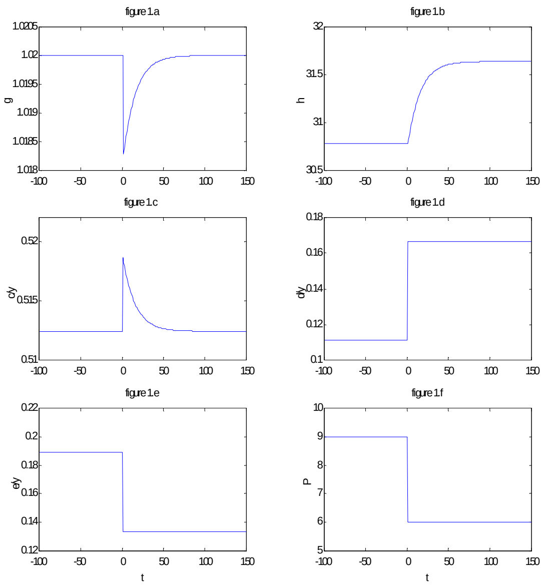

Figure 1: Transitional Dynamics (µ change)

The pace at which the economy reaches the new steady state is the result of the interaction between some e®ects. In the short-run, the stock of physical capital decreases, but inherits an increased trend after a while, and ¯nally its growth rate reaches its initial BC level. Thus, this policy induces a factorial reallocation e®ect, which reduces the intensity of physical capital in production.

A higher µ level increases the human capital-physical capital ratio (h) because the factor H is substituted for the factor K. In the beginning of the transitional dynamics, the crowding out e®ect of abatement reduces both the growth rate (see ¯gure 1.a) and the ratio of physical capital to production (see ¯gure 1.b). Increased abatement spending leads to a more human capital intensive ¯nal output. The immediate response to this policy is a sectorial reallocation of resources, which reduces the physical capital-human capital ratio.

4.3.2 Taxes structure change

The simulation of the transitional dynamics starts in period 0, where the government suddenly changes the Taxes structure change (Á). This ¯scal policy shock induces an

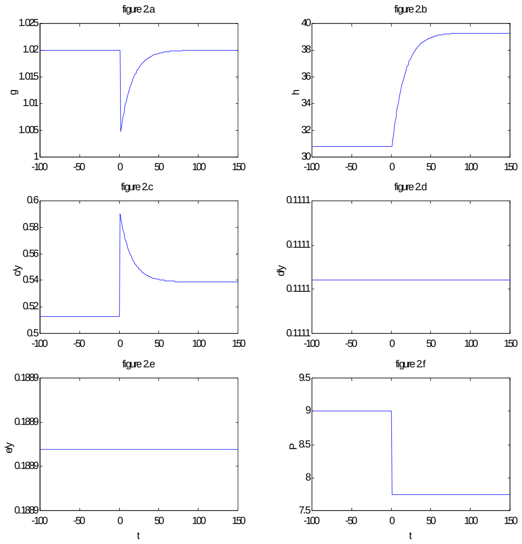

Figure 2: Transitional dynamics (Á change)

instantaneous reaction of all economic variables. We then observe di®erent impacts on the variables, which leave their initial level at BC and reach at di®erent rates their new level.

In the short-run, the stock of physical capital decreases, but inherits an increased trend after a while, and ¯nally its growth rate reaches its initial BC level.

A higher Á increases ¿^{K} and decreases ¿^{H}. In the beginning of the transitional dynamics, the crowding out e®ect of abatement reduces both the growth rate (¯gure 2.a) and the ratio of physical capital to production (¯gure 2.b). Abatement and education spending shares in the production are insensitive to the public policy shocks. Pollution °ow falls.

5 Welfare analysis

5.1 Welfare decomposition

We decompose welfare into transitional welfare (also referred to as the short-run welfare) $W_{1 ! 2}$ corresponding to the economy's transition from (BC) to a new steady state (NSS), and welfare related to the NSS W_2. So as to get a numerical result, we suppose that the transition from a steady state to another is achieved in a ¯nite amount of periods, and we simply denote T the date at which we consider that the economy has numerically reached its new rest point. The total welfare associated to the environmental policy change W^{Tot} is equal to the sum of utility flows, from $t = 0$ to ∞, which can be written as the sum of $W_{1\to 2}$ and W_2:

$$W^{Tot} = W_{1\to 2} + W_2 \tag{22}$$

Note that the economy converges only asymptotically to the steady state, and we therefore truncate the transitional dynamics in the effective computation at the horizon T. This horizon is chosen so that for all $t > T$, the difference between the value of physical capital stock at T (k_T) and its value at NSS (k_2) is numerically very small[4].

Formally, the transitional welfare can be written[5]:

$$W_{1\to 2} = \sum_{t=0}^{T} \beta^t \left[\log(c_t) + \sum_{i=0}^{t-1} \log(g_i) - \phi \log P_t \right] \tag{23}$$

the welfare related to the new steady state (NSS) is given by:

$$W_2 = \frac{\beta^{T+1}}{1-\beta} \left[\log c_2 + \sum_{i=0}^{T} \log g_i - \phi \log P_2 + \frac{\beta \log g_2}{1-\beta} \right] \tag{24}$$

and the welfare related to the BC steady state is given by[6]

$$W_1 = \frac{\log c_1 - \phi \log P_1}{1-\beta} + \frac{\beta \log g_1}{(1-\beta)^2} \tag{25}$$

5.2 Welfare cost:

To obtain a meaningful evaluation of the welfare cost associated to our policy change, we express all welfare measures as percentage point of the permanent consumption that generates an equivalent welfare in the benchmark case. Thus, our welfare cost measures the compensation in consumption terms that leaves the consumer indifferent between the BC consumption path and the NSS consumption path corresponding to a change in fiscal policy.

Let us define $\tilde{c}_2$ as the constant flow of consumption that gives a welfare W^{Tot} when pollution disutility and growth rate are constant.

[4] We tolerate a difference between k_T and $k(\tau^p)$ smaller than 10^{-10}.

[5] The formal computation of welfare decomposition is available on request.

[6] We assume that $K_{-1} = 1$

$$\tilde{e}_2 = \exp\left[(1-\beta) W_2^{Tot} - \frac{\beta}{1-\beta}\log g_1 + \phi \log P_1\right] \tag{26}$$

The total welfare cost is given by

$$\lambda = \frac{e_1}{\tilde{e}_2} - 1 \tag{27}$$

where

$$e_1 = \exp\left[(1-\beta) W_1^{Tot} - \frac{\beta}{1-\beta}\log g_1 + \phi \log P_1\right] \tag{28}$$

5.2.1 Welfare cost of spending shares change

Table 7 gives a number of welfare and welfare cost figures.

Table 7: Public spending shares change

	W^{Tot}	$W_{1\to2}$	W_2	W_1	λ
$\theta = 0.5\theta^{BC}$	-120.	-108.3005	-12.4956	-56.3027	0.9059
$\theta = \theta^{BC}$	-121.9579	-109.6143	-12.3437	-56.3027	0.9281
$\theta = 1.5\theta^{BC}$	-123.3629	-111.1082	-12.2548	-56.3027	0.9554

We look at the welfare cost of revenue-equivalent increases in the abatement share. Higher is the abatement share, higher is the welfare cost.

5.2.2 Welfare cost of taxes structure change

Table 8 gives a number welfare of welfare costs induced by a tax reform.

Table 8: Taxes structure change

	W^{Tot}	$W_{1\to2}$	W_2	W_1	λ
$\phi = 0.5\phi^{BC}$	-128.356	-110.7873	-17.5689	-56.3027	1.0555
$\phi = \phi^{BC}$	-121.9579	-109.6143	-12.3437	-56.3027	0.9281
$\phi = 1.5\phi^{BC}$	-117.9011	-110.0112	-7.8899	-56.3027	0.8515

We show that when we increase physical capital tax we have a lower welfare cost.

6 Conclusion

We have studied in this paper the short-run and long-run behavior of an economy responding to two kind of public policy. The model used is a version of a two sector endogenous growth model within an environmental externality. Our ambition was to explored the e®ects of both tax change and expenditures structure on the welfare. We showed that a public policy which centre on spending structure leads a higher welfare cost. However, government might reduce welfare cost with a revenue-equivalent physical capital increases.

In a later version, we will explore the same public policy trade-o®s when the growth rate is a®ected.

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