Corporate Tax Competition and Public Capital Stock[*]

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Abstract

This paper argues that the governmental decisions on corporate tax and public capital stock are not independent. In order to explain this relationship, we have built a general equilibrium model of corporate tax competition where governments supply public capital and compete for corporate profits. When international tax competition drives the statutory tax rate down from 50% to 30%, public capital stock goes down by 10% of GDP. To confirm this relation, we estimate two policy functions for 18 OECD countries. We find that corporate tax rate and public investment are endogenous and that a decline of 20% in the corporate tax rate, driven by competition, reduces public investment by 0.5% to 0.9% of GDP. We also find evidence that there is international competition in both policy tools and that tax competition increases with the degree of openness of the economy.

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Non technical summary

Over the past 30 years, there has been a downward trend in two distinct government policy tools. On the one hand, corporate tax rates have gone down in the majority of the OECD countries from around 50% to 30%. On the other hand, public investment has declined from an average of 4.5% of GDP to below 3% of GDP. As a consequence, public capital stock has fallen by 10% of GDP.

The decline of corporate tax rate is usually attributed to international tax competition and a higher degree of capital mobility. However, the growing internalization of the corporate sector has created another source of tax competition: multinational companies have indeed the possibility to change the location of their declared profit in response to tax rates differentials for tax evasion purposes. Such phenomenon is likely to be quite common in Europe since the implementation of the single market has dramatically increased the international mobility of the corporate sector.

The literature regarding the downward trend in public investment is scarcer and far less compelling. In a way, the decline of public investment and public capital stock is a puzzle as we would expect countries to increase their stock of public capital in order to attract more private investment.

In this paper, we argue that the globalization of the OECD economies, with the subsequent increase in tax rate competition, has produced side effects on public spending by driving public investment and public capital stock down. To make our case, we first build a model of tax competition with a productive and durable public good in order to assess the long-term implications of a greater degree of corporate tax competition. We then perform an empirical analysis for 18 OECD countries for the period between 1960 and 2005.

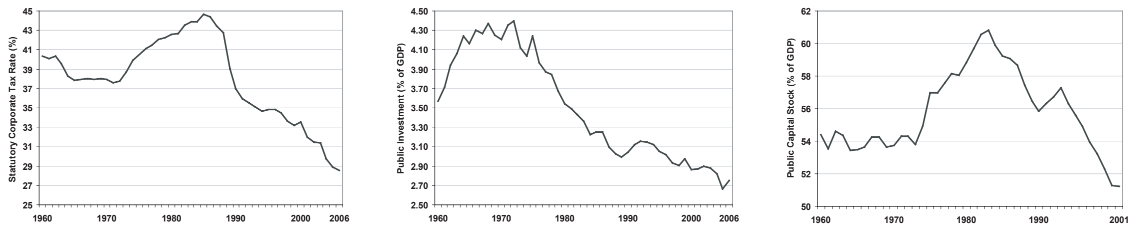
Our model of corporate tax competition illustrates the interdependence of statutory tax rates and productive spending. We develop our analysis in a general equilibrium setting, in this way we can aim to do a more realistic quantitative analysis. In our two-country model, governments can enlarge their tax base by deciding on a more accommodating corporate tax rate or by increasing the stock of productive public capital (or public infrastructures). The national tax base depends on the declared profit of the corporate sector in each country. Profit can be shifted from one country to another for tax evasion purposes. These profit shifting operations introduce crucial strategic interactions at the origin of a race to the bottom phenomenon. Our simulations indicate that following a decline of 20% in tax rate (driven by increasing competition), public investment diminishes between 0.2% and 0.4% of GDP. This leads to a drop in public capital stock over output ranging from 5 to 10 percentage points. We also create different scenarios and challenge the robustness of the relationship. In all cases, international tax competition drives the stock of public capital down.

In the empirical part we estimate two endogenous policy functions of corporate tax rate and public investment that also respond to their foreign counterpart. Evidence confirms the endogeneity and the complementarity between the two tools: tax rate increases with the level of public investment and public investment increases with the tax rate. We find that a decline in tax rate of 20%, reduces public investment between 0.5% and 0.9% of GDP. Further evidence suggests that there is competition in both tools. Corporate tax rate and public investment respond to changes in the values set by foreign countries. In the case of the corporate tax rate, this international competition increases with the level of openness of the economy.

1 Introduction

Over the past 30 years, there has been a downward trend in two distinct government policy tools. On the one hand, corporate tax rates have gone down in the majority of the OECD countries from around 50% to 30%. On the other hand, public investment has declined from an average of 4.5% of GDP to below 3% of GDP. As a consequence, public capital stock has fallen by 10% of GDP (see Figure 1 below).

Figure 1: Corporate Taxation and Productive Public Spending



Average over 18 OECD countries. Details in appendix.

The decline in corporate tax rate is usually attributed to international tax competition and a higher degree of capital mobility.[1] However, the growing internalization of the corporate sector has created another source of tax competition: multinational companies have indeed the possibility to change the location of their declared profit in response to tax rates differentials for tax evasion purposes. Bartelsman and Beetsma (2003) performed an empirical analysis based on OECD countries and estimate in their baseline scenario that 65% of the additional revenue from a unilateral tax increase is lost due to a decrease in the reported profit to the national tax authorities.[2] Such phenomenon is likely to be

[1]Corporate tax competition is a relatively well documented phenomenon, see for instance Krogstrup (2004).

[2]See also Huizinga and Laeven (2007) who have calculated that the average semi-elasticity of reported

quite common in Europe since the implementation of the single market has dramatically increased the international mobility of the corporate sector.

The literature regarding the downward trend in public investment is scarcer and far less compelling.[3] In a way, the decline of public investment and public capital stock is a puzzle. Bénassy-Quéré, Gobalraja, and Trannoy (2005), among others, show for instance that the location of multinational firms does not entirely depends on national tax policies but also on 'public infrastructure', partly because of its positive effect of the productivity of private capital. Under these circumstances, the relationship displayed in Figure 1 could appear counter-intuitive: in a more "competitive" environment we would indeed expect countries to increase their stock of public capital in order to attract more private investment.

In this paper, we argue that the globalization of the OECD economies, with the subsequent increase in tax rate competition, has produced side effects on public spending by driving public investment and public capital stock down. To make our case, we first build a model of tax competition with a productive and durable public good in order to assess the long-term implications of a greater degree of corporate tax competition. We then perform an empirical analysis for 18 OECD countries for the period between 1960 and 2005.

In line with Pouget and Stéclebout-Orseau (2008, 2007), our model of corporate tax competition illustrates the interdependence of statutory tax rates and productive spending.

profits with respect to the top statutory tax rate. In particular, Germany appears to have lost considerable tax revenues due to profit mobility -see Zeichenrieder (2007).

[3] Some frequent explanations for the decline of public investment include: the increase of privatization, the increase of private-public partnerships, the smaller role of the government or, in the case of Europe, the need for fiscal stringency. Some of these explanations are not very convincing as argued by Mehrotra and Välilä (2006). First, under national accounts, the investment undertaken by public enterprizes counts as private investment. Only counts as public investment investment recorded and financed from the budget. Second, private and public partnership is a very recent phenomenon that could not account for the pattern observed since the 1970s. Furthermore, public consumption has increased during the same period for most OECD countries. Studies of the determinants of public investment include Haan, Sturm, and Sikken (1996), Randolph, Bogetic, and Hefley (1996) or Balassone and Franco (2000).

We develop our analysis in a general equilibrium setting, in this way we can aim to do a more realistic quantitative analysis. In our two-country model, governments can enlarge their tax base by deciding on a more accommodating corporate tax rate or by increasing the stock of productive public capital (or public infrastructures). The national tax base depends on the declared profit of the corporate sector in each country. Profit can be shifted from one country to another for tax evasion purposes. These profit shifting operations introduce crucial strategic interactions between the countries.[4] Our simulations indicate that following a decline of 20% in tax rate (driven by increasing competition), public investment diminishes between 0.2% and 0.4% of output. This leads to a drop in public capital stock over output ranging from 5 to 10 percentage points. We also create different scenarios and challenge the robustness of the relationship. In all cases, international tax competition drives the stock of public capital down.

In the empirical part we estimate two endogenous policy functions of corporate tax rate and public investment that also respond to their foreign counterpart. Evidence confirms the endogeneity and the complementarity between the two tools: tax rate increases with the level of public investment and public investment increases with the tax rate. We find that a decline in tax rate of 20%, reduces public investment between 0.5% and 0.9% of GDP. Further evidence suggests that there is competition in both tools. Corporate tax rate and public investment respond to changes in the values set by foreign countries. In the case of the corporate tax rate, this international competition increases with the level of openness of the economy.

The next section of this paper introduces the theoretical model by presenting the main assumptions and mechanisms in a partial equilibrium setting. In the third section we

[4] For other contributions on international tax competition and profit shifting, see Kind, Midelfart, and Schjelderup (2005) and Elitzur and Mintz (1996).

calibrate the model and present the results from our simulations. Our general equilibrium analysis enables us to assess and quantify the relation between public capital stock and international tax competition. The empirical analysis is presented in the fourth section. The last section concludes.

2 The Model

The model consists of two countries, denoted A and B. National governments decide on the corporate tax rate, the investment in a productive public good and the supply of an unproductive composite public good. The corporate sector is introduced through a single representative multinational firm producing an homogeneous good in both countries. Capital is perfectly mobile between the two countries and the firm can borrow at a world interest rate. Since the two national tax bases are not consolidated, the corporate sector has the ability to shift profit for tax evasion purposes but these operations entail a cost. In this simple model, there is perfect foresight and no uncertainty

2.1 The Households

In each country i ($i \in \{A; B\}$), a representative household derives its utility from both private and public consumptions. The instantaneous utility function at time t is given by:

$$U_t^i = \ln c_t^i + \xi \ln g_t^i + \gamma \ln P_t^i \tag{1}$$

Public consumption takes two forms: g_t^i (a non-rival and non-excludable public good) and public capital stock (P_t^i). g_t^i can be viewed as a composite public good covering all types of public spending with no direct productive purposes. It is non-durable and is measured in terms of public spending allocated to its production for each period t. P_t^i represents a wide range of productive public infrastructures such as roads and bridges. As we will explain later on, P_t^i enters in the household's utility function but it is also used in the production process. This distinction is in line with the one developed by Keen and Marchand (1997), except from the fact that we consider "productive" spending to be a durable good, accumulated over time. Parameters ξ and γ tell us that the representative household can valuate differently these two dimensions.

In each country, the representative household takes the governmental choice on public consumption as given and maximizes the present discounted value of the lifetime utility of private consumption: $\hat{U}(c_t^i) = \sum_{t=0}^{\infty} \beta^t \ln c_t^i$, β being the discount factor. The household's budget constraint is described by:

$$c_t^i + I_t^i = w_t^i + r_t^k B_t^i + \Upsilon_t^i - \bar{t} \tag{2}$$

In each period, household's resources are either consumed (c_t^i) or saved by holding shares of the private sector (I_t^i). We assume that the representative household supplies one unit of labour inelastically and wage rate is set at w_t^i. Total net resources depend also on the total amount of private capital owned by the household, denoted B_t^i, which yields a gross return of r_t^k and whose law of motion (assume that the depreciation rate of private capital is δ) is:

$$B_{t+1}^i = (1 - \delta)B_t^i + I_t^i \tag{3}$$

The household receives also dividends earned by the private sector: Υ_t^i (which will be defined later on). Besides, a lump sum tax on personal income, $\bar{t}$, is levied in order to finance public policy. Note that this specific tax rate will be considered exogenous in this model. Maximizing $\hat{U}(c_t^i)$ subject to (2) gives us the consumption pattern of the representative household, which is determined by the following Euler condition (we define $r_t = r_t^k - \delta$ as the net interest rate):

$$c_{t+1}^i = c_t^i(1 + r_{t+1})\beta \tag{4}$$

2.2 The Corporate Sector

A single multinational firm operating in the two countries represents the private sector. It produces an homogeneous private good according to the following production function:

$$y_t^i = F(k_t^i, P_t^i, n_t^i) = k_t^{i\alpha} P_t^{i\theta} n_t^{i(1-\alpha-\theta)} \tag{5}$$

The labor input, n_t^i, is considered to be immobile between the two countries. By contrast, capital is perfect mobile and k_t^i describes the total quantity of capital used in country i. Public capital stock is included in the production function and therefore increases the marginal productivity of capital. P_t^i is considered as given by the firm. Note also that the production technology is identical in the two countries.

A source-based corporate tax is applied on the declared profit of the representative firm in the two countries. Therefore, the aggregated net profit of the corporate sector is as follows:

$$\Pi_t^{Tot} = (1-\tau_t^A)\Gamma_t^A + (1-\tau_t^B)\Gamma_t^B - r_t(k_t^A + k_t^B) - \psi(S_t)$$

$$\text{with: } \begin{cases} \Gamma_t^A = F(k_t^A, P_t^A) - w_t^A - \delta k_t^A - s_t \\ \Gamma_t^B = F(k_t^B, P_t^B) - w_t^B - \delta k_t^B + s_t \end{cases} \tag{6}$$

Γ_t^i represents the declared profits of the firm in country i , and therefore its corporate tax base. We assume that the firm can deduce capital depreciation from the taxable profits. We define $s_t > 0$ (respect. < 0) the total amount of profit shifted form country A to country B (respect. from B to A). These profit manipulations are costly to the firm since national tax authorities seek to prevent tax evasion (for instance, transfer pricing distortions have to be justified). The function $\psi(s_t)$ capturing this cost is convex: $\psi(0) = 0$, $\psi_s(s_t) > 0$ and $\psi_{ss}(s_t) > 0$.[5] Following Kolmar and Wagener (2006), we use the following functional form: $\psi(S_t) = b(s_t)^2$.

By maximizing 6 with respect to k_t^i, w_t^i and s_t, we obtain the behavior of the corporate sector. The allocation of capital between the two countries depends on the following first order condition:

$$F_K(k_t^{i*}, P_t^i, n_t^i) = \upsilon_t^i + \delta \text{ with: } \upsilon_t^i = \frac{r_t}{(1-\tau_t^i)} \tag{7}$$

Therefore, total amount of capital used in country i is such that its marginal productivity equals the gross cost of capital (which includes the cost of depreciation). Net cost of capital in a given country, υ_t^i, is increasing with interest rates and corporate tax

[5]This cost should be interpreted as the probability of being audit by the authorities, not being able to justify the transfer prices, and consequently being fined. We therefore assume that the marginal cost of tax evasion increases with the total amount of profit shifted.

rate. Besides, because of perfect mobility of capital, a unique interest rate applies in the two countries. When the government increases the total stock of public capital, P_t^i, this automatically increases k_t^{i*} due to its positive effect on marginal productivity of capital.

As one unit of labour is inelastically supplied in the two countries, the firm's decision on labor consists on the choice of the wage rate according to the following condition:

$$F_n(k_t^i, g_t^i, n_t^i) = w_t^{i*} \tag{8}$$

At last, firm's decision on paper profit responds to the tax rate differential. Because $\psi_s(s_t) > 0$, profit will be shifted from A to B if $\tau_A - \tau_B > 0$. Profit-shifting flows are a decreasing with marginal cost associated to these operations:

$$\psi_s(s_t^*) = \tau_t^A - \tau_t^B \Leftrightarrow s_t^* = \frac{\tau_t^A - \tau_t^B}{2b} \tag{9}$$

2.3 The government

The purpose of the government is to maximize the present discounted value of the household lifetime utility on public consumption. We assume that the household' preferences for public consumption are fully respected by their respective decision maker so that the governmental objective function will be:

$$V(P_t^i, g_t^i) = \sum_{t=0}^{\infty} \beta^t \left(\xi \ln g_t^i + \gamma \ln P_t^i \right) \tag{10}$$

Our government behaves like a benevolent leviathan. It is a leviathan because it would want to increase the supply of public good unlimitedly. It is benevolent because it will respect the household preferences when allocating the public resources between the composite public good, g_t^i and public investment p_t^i.[6].

Public resources in country i depend on the personal and corporate income tax revenue. Corporate tax revenue R_t^i depends on a statutory tax rate and the corporate tax base (i.e. the declared profit of the firm in country i).

$$
\begin{gathered}
g_t^i + p_t^i = \bar{t} + R_t^i(P_t^i, \tau_t^i, \tau_t^j) \\
\text{with: } R_t^i(P_t^i, \tau_t^i, \tau_t^j) = \tau_t^i \Gamma_t^i = \tau_t^i [F(k_t^{i*}, P_t^i, n_t^i) - \delta k_t^{i*} - w_t^{i*} \pm s_t^*]
\end{gathered}
\tag{11}
$$

The second constraint the government faces is the law of motion equation of public capital (δ_p is the rate of depreciation) :

$$
P_t^i = (1 - \delta_p) P_{t-1}^i + p_t^i \tag{12}
$$

We consider that the governments anticipates the outcome of their choice on the decisions of the private sector. In this sense it knows that both its decision on tax rate and public capital affect the firm's choice of capital (7), labour (8) and profit shifting (9) and therefore the corporate revenue. Public decision consist of the choice of a statutory tax rate, τ_t^i and a decision on public resources allocation between the provision of the

[6]An alternative way to interpret the government's problem is to think the government maximizes consumer's lifetime utility but is limited on the amount of taxes it can collect ($\bar{t}$). If the consumers have strong preferences for the public goods, the supply of public goods is always below optimum. The level of consumption is very high and its marginal benefit too low compared to both public goods. In this case the government's problem collapse to (10)

non-productive public good and an increase of the public capital stock. Each government decides simultaneously and non-cooperatively.

The Lagrangian associated with the government allocation problem is:

$$L = \sum_{t=0}^{\infty} \beta^t \{ \xi \ln \left[\bar{t} + R_t^i(P_t^i, \tau_t^i, \tau_t^j) - p_t^i \right] + \gamma \ln P_t^i - \lambda_t \left[P_{t+1}^i - (1-\delta_p) P_t^i - p_t^i \right] \} \tag{13}$$

Not surprisingly, the government chooses τ_t^i in order to maximize its corporate tax revenue:

$$\frac{\partial R_t^i(P_t^i, \tau_t^i, \tau_t^j)}{\partial \tau_t^i} = 0 \tag{14}$$

Since a corporate tax rate policy is decided simultaneously and non-cooperatively by the two countries, tax equilibrium between A and B is therefore the outcome of a Nash game. Using (14) we obtain the reaction functions of the two countries (see Appendix 6.A):

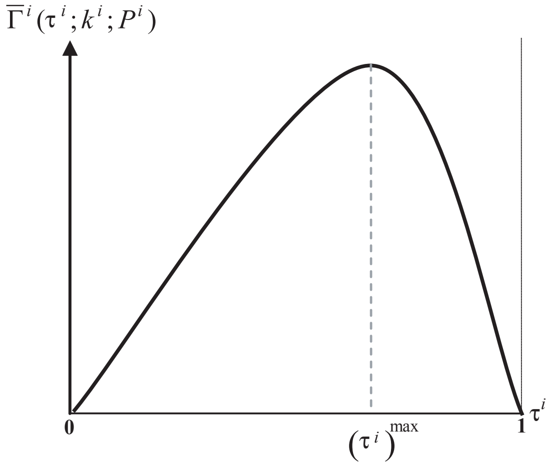
$$\begin{cases} \frac{\tau_t^A}{b} = \frac{\tau_t^B}{2b} + \frac{\partial \bar{\Gamma}_t(k_t^A; \tau_t^A; P_t^A)}{\partial \tau_t^A} \\ \frac{\tau_t^B}{b} = \frac{\tau_t^A}{2b} + \frac{\partial \bar{\Gamma}_t(k_t^B; \tau_t^B; P_t^B)}{\partial \tau_t^B} \end{cases} \tag{15}$$

A corporate tax policy stance has two major determinants. Firstly, each government attempts to maximize the revenue of its "productive" tax base, denoted $\bar{\Gamma}(.)$. This consists of the tax base that would be only determined through the allocation of capital:

$$\bar{\Gamma}(\tau_t^i; k_t^i; P_t^i) = \tau_t^i \left\{ (P_t^i)^{\frac{\theta}{1-\alpha}} \left(\frac{\alpha}{\upsilon_t^i + \delta} \right)^{\frac{1}{1-\alpha}} \left[\frac{\upsilon_t^i + \delta(1-\alpha)}{\alpha} \right] - w_t^i \right\} \tag{16}$$

As one can observe on Figure 2, the revenue derived from this fraction of the tax base follow the pattern of a traditional Laffer curve with respect to the corporate tax rate and is maximized for $\tau_i^{\max}$. When $\tau_t^i > \tau_{\max}^i$, any corporate tax hike would entail a net loss because the marginal revenue would be offset by the shrinking of the tax base.

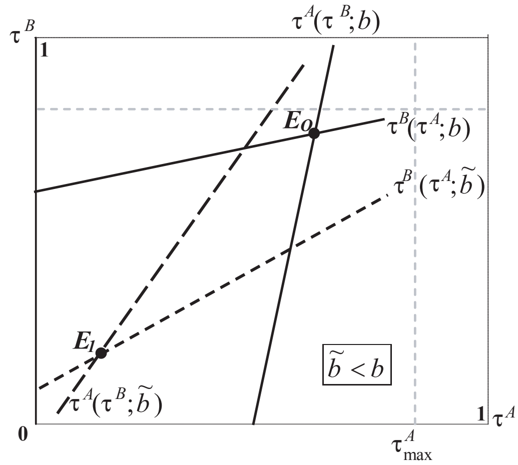
Figure 2: The "Productive" Tax Base



The second determinant of a corporate tax policy is easily observed on (15): tax rate in a given country is clearly responding to its partner's tax rate. These strategic interactions describe a race to the bottom phenomenon which is entirely dependent on profit mobility. When b is low, the multinational firm can engage profit shifting operations forcing the two countries to compete more (see Figure 3). On the other hand, if profit shifting operations were no longer affordable ($b \rightarrow +\infty$), strategic interactions would disappear and corporate tax rates would be set at $\tau_{\max}^i$.

Having described in details the nature of tax competition in this model, we can now an-

Figure 3: Tax Rate Equilibrium



alyze the determination of the stock of public capital in our model, we obtain the following first order condition:

$$\frac{\xi}{g_t^i} = \beta[\frac{\gamma}{P_{t+1}^i} + \frac{\partial R_{t+1}^i(P_{t+1}^i, \tau_{t+1}^i, \tau_{t+1}^j)}{\partial P_{t+1}^i}\frac{\xi}{g_{t+1}^i} + (1-\delta_p)\frac{\xi}{g_{t+1}^i}] \tag{17}$$

When maximizing (13) with respect to p_t^i we obtain: $\lambda_t = \xi/g_t^i$, so that the Lagrange multiplier can be interpreted as the marginal cost of public investment in t (in terms of households foregone utility of consumption of the public good). The right hand side represents the discounted benefits of investing in public capital. It is composed of the direct benefit of public capital on the representative household utility (γ/P_{t+1}^i). The second component of the benefit refers to the anticipated effect of public capital stock on tax revenue: investing more on public capital, will drive the multinational firm to install more capital, bringing therefore an extra revenue in the future. This revenue may then be used to supply a general public good to the population. The third component reflects the fact that public capital is a durable good so these two effects carry on to the following periods after depreciation is accounted for.

Using (4) we can re-writing (17) at the steady state, to obtain:

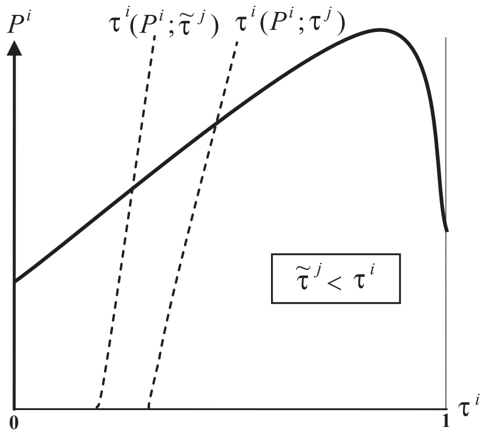
$$\frac{\partial R^i(P^i,\tau^i,\tau^j)}{\partial P^i}+\frac{\gamma}{\xi}\frac{g^i}{P^i}=r+\delta_p \tag{18}$$

The interpretation of (18) is very simple. The marginal benefit of an increase of public capital stock depends on its positive effect on corporate tax revenue and the marginal utility that the representative household derives from this public policy (which is of course decreasing with P^i). The gross marginal cost increases with interest rate and the depreciation rate of public capital stock.

We can observe by the first order conditions (14) and (17) that the two instruments used by the decision maker in order to collect corporate tax revenue are interdependent. We illustrate this partial equilibrium relationship for country A on the Figure 4 below. Except for extreme values of τ_t^A, the stock of public capital is increasing with the statutory tax rate. This pattern directly depends on how strong is the impact of public capital on total corporate tax revenue ($\partial R^i(P^i,\tau^i,\tau^j)/\partial P^i$), which obviously declines when tax rate takes lower values. Note that total capital stock remains positive even when tax rate is equal to zero (indeed, as we can clearly see on (18), public capital stock does provide a satisfaction to the representative household besides increasing future tax revenue and therefore does not disappear even in the absence of corporate taxation).

On the other hand, tax rate depends positively on the level of public capital. The higher the public capital, the higher the rents are, so the higher the governments will set their tax rate. Nevertheless, tax rate appears to be less reactive to public capital stock. In our model the tax policy stance relies mostly on the level of tax competition and on the partner country's tax rate.

Figure 4: First Order Conditions



2.4 Market Clearing

In order to close the model we need three additional conditions. First we have the market clearing condition for both capital and goods markets:

$$\begin{cases} b_t^A + b_t^B = k_t^A + k_t^B \\ y_t^A + y_t^B = c_t^A + c_t^B + g_t^A + g_t^B + p_t^A + p_t^B + I_t^A + I_t^B + b(s_t)^2 \end{cases} \tag{19}$$

Total capital used by the firm equals the amount of capital held by the households. Total production in the two countries must equal total private and public consumption, private and public investment and the cost of profit shifting. Finally we need a final equation to pin down the consumption level of each country.

$$c_t^i + I_t^i = w_t^i + r_t b_t^i - \bar{t} + \Upsilon_t^{i7} \tag{20}$$

3 General Equilibrium analysis

In this section we analyze the implications of corporate tax competition in a general equilibrium setting. Although the model is not very complex it does not have a closed form solution. Therefore we proceed by calibrating the parameters (see Table 1 below) and solving the non-linear system at the steady state.

Table 1: Calibration and Steady State Values in the Benchmark Case

Calibration			**Steady State**		
β	discount factor	0.96	c/y	Consumption / output	0.48
δ	depreciation rate (private capital)	0.08	I/y	Investment / output	0.17
δ_p	depreciation rate (public capital)	0.04	$(g+p)/y$	Public spending / output	0.35
α	elasticity of output (private capital)	0.26	p/y	Public investment / output	0.02
θ	elasticity of output (public capital)	0.07	k/y	Private capital stock / output	2.11
$\bar{t}$	Lump sum taxe	0.376	P/y	Public capital stock / output	0.50
$\frac{\gamma}{\xi}$	Relative preference for public capital	0.15	τ	Corporate tax rate	0.30
b	cost of profit shifting	0.16	R/y	Corporate tax revenue / output	0.048

The calibration of the first four parameters is quite standard. The discount factor is such

[7] We defined the dividend paid in country i as the total declared profit minus the interest rate payment on existing capital.
$\Upsilon_t^i = [(1-\tau_t^i)(y_t^i - w_t^i - \delta k_t^i - s_t) - r_t k_t^i]$

that the annual real interest rate is 4%. Following Kamps (2006), the annual depreciation of public capital is 4%, half of its private counterpart. The elasticity of output with respect to private capital is 0.26. The parameter θ is more controversial. Estimates of the elasticity of output with respect to public capital range from 0 to 0.80. We set the value to 0.07 following a meta-analysis study of Bom and Ligthart (2008).

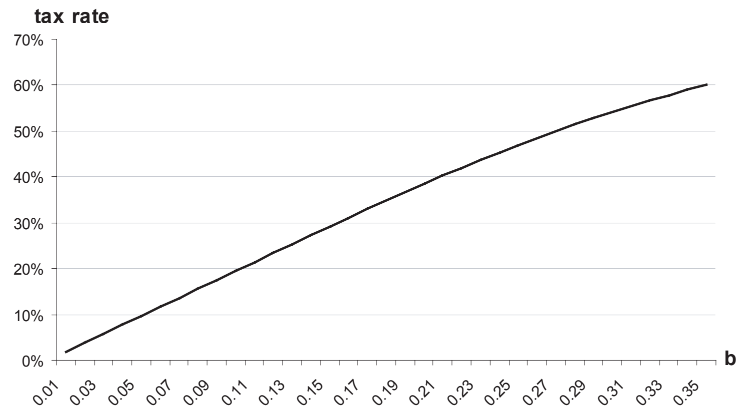
The last three coefficients are calibrated in order to obtain realistic steady state values for some variables. As we do not have any estimation of the cost parameter of profit shifting, b is set such that corporate tax rate equilibrium is 30 percent. The relative preference for the two types of public goods, γ/ξ, is such that public capital stock as a share of output in equilibrium is 0.5. These two values are in line with the reality in the largest OECD countries. The lump sump tax $\bar{t}$ is such that the overall weigh of the government in the economy is close to 35 percent of output, which is slightly lower than its real value in some European countries but realistic for the US.

3.1 Tax competition and public capital stock

Starting from this baseline calibration, we now analyze the consequences of tax competition on public capital stock and other key variables in the economy. We first reproduce the result of the previous section in this general equilibrium framework. Figure 5 below illustrates how the tax rate equilibrium depends on the cost of profit shifting. We observe that when profit shifting becomes more affordable, a race to the bottom occurs. Not surprisingly in the extreme case of perfect profit mobility, tax rate is driven to zero.

The Figure 6 below shows how the steady state stocks of public capital and public investment over output respond to changes in the tax rate (driven by the decline in b).

Figure 5: Tax Rate Equilibrium and the Cost of Profit Shifting



Under the benchmark scenario, a change of the statutory tax rate from 50% to 30% percent leads to a decline of public capital stock of 10% of output and a decline of public investment of 0.4% of output.

The overall effect of increasing competition can be decomposed in two: the revenue and substitution effects. On the one hand, a decline in the tax rate reduces revenue thus reducing the level of public investment, as well as the provision of the general public good. On the other hand, reduction of the tax rate makes public investment less attractive in relation to the general public good. The overall decline might be however over-estimated because of the influence of the revenue effect. In reality, this effect is indeed likely to play a minor role since one can that the total tax revenue derived from corporate taxation has remained relatively stable despite the fall of the statutory tax rate. In order to isolate the substitution effect in our analysis, we artificially control for the revenue effect by changing $\bar{t}$ such that total revenue is kept constant (see the dash lines in Figure 6). The decline of public capital and public investment would be half, 5% and 0.2% of output respectively.

Figure 6: Public Capital Stock and Corporate Tax Rate

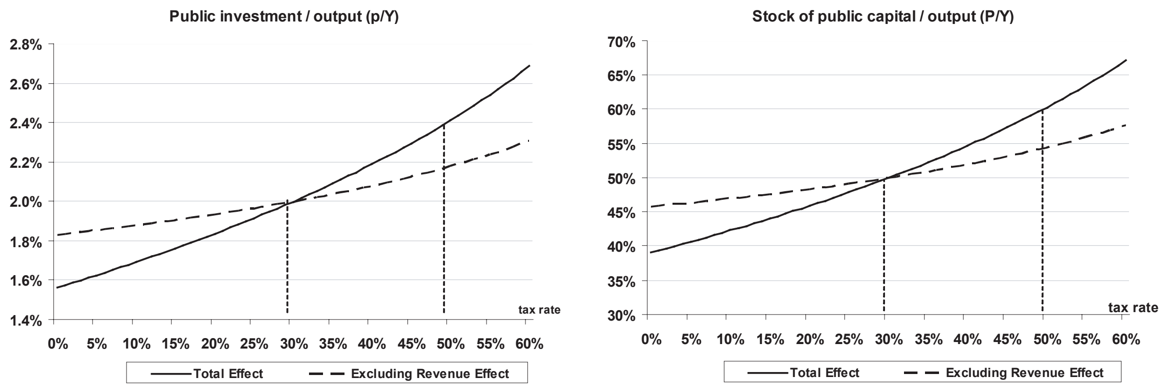
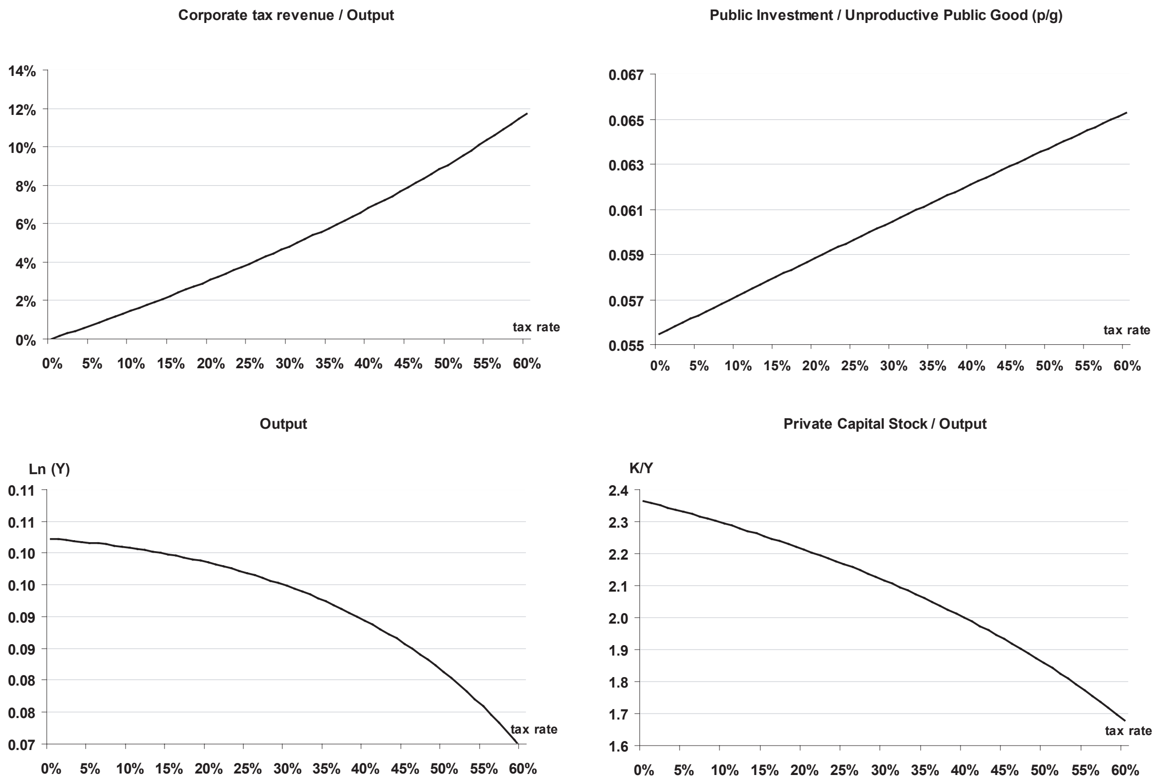


Figure 7 depicts the steady state response of some macroeconomic variables to changes in competition. The first two graphs illustrate the revenue and substitution effects. As tax rate decreases, corporate tax revenue goes down. In the extreme case of competition, corporate taxation disappears. The substitution effect is visible in the ratio of public investment and in the general public good. As tax rates are driven to lower levels, we indeed observe a shift in the composition of public spending in favour of the unproductive composite public good.

The final two graphs show that both private capital and output go up with the increase in tax competition. Private capital increases because the effect of the tax rate reduction on the cost of capital is stronger than the negative effect of the public capital reduction on the marginal productivity of private capital. Output increases because the increase of private capital more than compensates for the reduction of public capital. Although this is a feature of our benchmark calibration, it is not a general statement. Under different parameterizations, for instance if the production process relies heavily on P^i, it is possible that with the increase in competition both private capital and output would fall.

Figure 7: The Effect of Corporate Tax Rate on Key Variables



3.2 Robustness analysis

Having described the main effects of corporate tax competition on our benchmark model, we now consider different realistic scenarios. For all of them, we analyze the evolution of public capital stock. We observe that the main conclusion of the first section is confirmed: corporate tax competition has a negative impact on the stock of public capital. The quantitative prediction is also quite robust. Public capital stock over GDP falls between 7% and 15% of output and public investment between 3% and 6% of output under the alternative scenarios. The substitution effect accounts for close to half of the total effect.

Table 2: Robustness Analysis

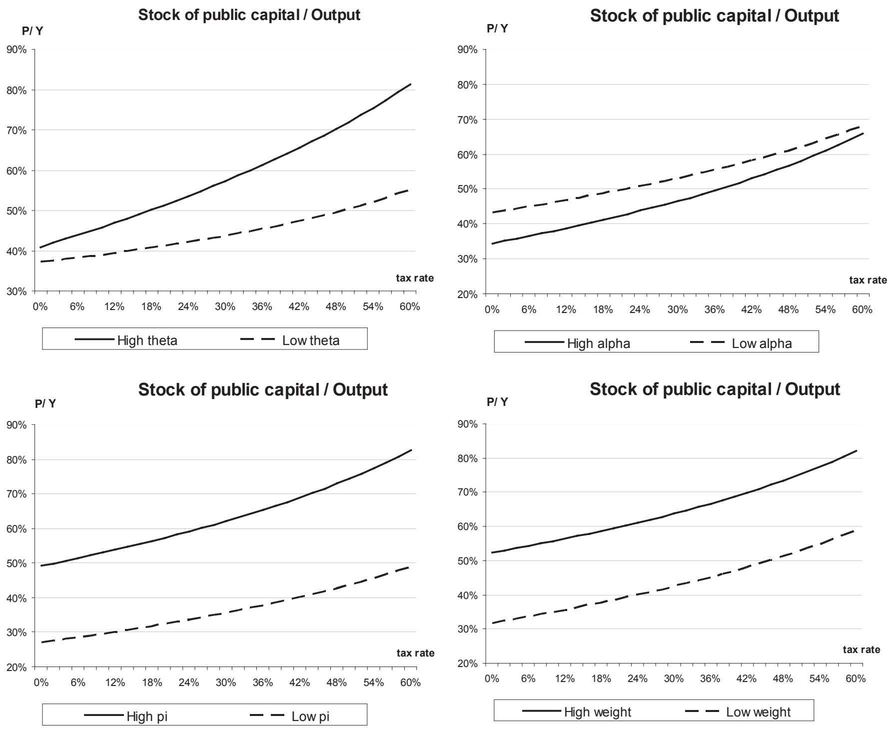
Alternative scenarios		**Public capital stock**				**Public Investment**			
	Parameters	$\tau = 50\%$	$\tau = 30\%$	TE	SE	$\tau = 50\%$	$\tau = 30\%$	TE	SE
1.high theta	$\theta = 0.12$	72.0%	57.3%	14.7%	6.6%	2.9%	2.3%	0.6%	0.3%
2.low theta	$\theta = 0.02$	50.4%	43.7%	6.7%	2.6%	2.0%	1.7%	0.3%	0.1%
3.high alpha	$\alpha = 0.30$	58.1%	46.5%	11.5%	5.0%	2.3%	1.9%	0.5%	0.2%
4.low alpha	$\alpha = 0.22$	62.1%	53.1%	9.1%	3.9%	2.5%	2.1%	0.4%	0.2%
5.high pi	$\gamma/\xi = 0.2$	74.3%	62.1%	12.2%	4.8%	3.0%	2.5%	0.5%	0.2%
6.low pi	$\gamma/\xi = 0.1$	43.8%	35.7%	8.1%	4.0%	1.8%	1.4%	0.3%	0.2%
7.high weight	$\bar{t} = 0.52$	74.7%	63.8%	10.9%	5.2%	3.0%	2.6%	0.4%	0.2%
8.low weight	$\bar{t} = 0.3$	52.5%	42.5%	10.0%	4.0%	2.1%	1.7%	0.4%	0.2%

Since the value of parameter θ has involved a lot of controversies, we test alternative values for the contribution of public capital stock on private output (scenarios 1 and 2). For this reason, and despite the fact that our calibration is in line with the recent estimations given by the literature, we simulate two extreme cases. When P^i has a minor effect on output, the initial stock of public capital is lower at the steady state and exhibits a lower variability with tax rates. However, public capital stock remains significant since it is also provided to households. By contrast, when θ is relatively high, we observe that tax competition entails a large drop of public capital stock.

Allowing different values for α (scenarios 3 and 4) affects the substitutability between private and public capital. Not surprisingly, when the production process relies relatively more on private capital, we observe a greater decline of public capital stock. Scenarios 5 and 6 describe the effect of a change of the relative preferences of the society for the two public policy dimensions. Without doubt, preference has a relatively high impact of the level of public capital stock but less on its pattern. Therefore it appears that a change in preferences is not likely to affect the main mechanism of our model. Analyzing the impact of the variation of the exogenous tax rate leads to the same conclusions. The total stock of public capital increases with $\bar{t}$, whose real value is a major determinant of the scope of government.

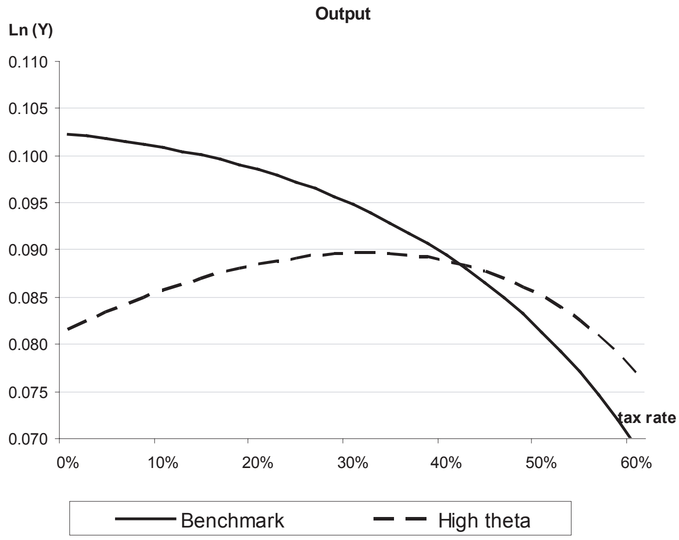
The relationship between corporate tax rate and the stock of public capital appears relatively robust since changing the value of the parameters does not affect the main mechanism of the model and major macroeconomic variables. This is true for all parameter except θ, the contribution of public capital stock on output, which reveals much more sensitivity than others. This sensitivity has an important side-effect on total output as we can observe on Figure 9. In the benchmark case ($\theta = 0.07$) a race to the bottom of corporate tax rate has always a positive effect on total output because it reduces the cost of private capital. However, when we consider a greater contribution of public capital, a reduction of tax rate can be counter-productive on total output. This is explained by the fact that public stock increase the marginal productivity of private capital. This productivity is deteriorated when tax competition reduces total capital stock. When the production process relies heavily on P^i and tax competition is strong, this negative effect cannot be compensated by the fact that private capital is now more affordable due to the tax cuts.

Figure 8: Public Capital Stock under Different Calibrations



Therefore, the total effect on output is negative. For higher but realistic value of θ there exist therefore a threshold tax rate under which corporate tax competition is harmful for production. When $\theta = 0.1$, the threshold tax rate is reached at 18 percent and if $\theta = 0.12$, tax competition is "harmful" when $\tau = 32\%$, which is a relatively high value.

Figure 9: Total Output and Corporate Tax Rate with High Theta



4 Empirical Analysis

4.1 Setting

Our model illustrates the interdependence of public capital and corporate tax rate in a very particular setting. In reality, governments compete not only for corporate profits, but also for private investment. Furthermore, there might be other elements that determine the complementarity or substitutability between the two tools. In our empirical setting we try to be very general. Our objective is to estimate two policy functions for corporate tax rate (tax_{it}) and public investment (inv_{it}) in the spirit of Devereux, Lockwood, and

Redoano (2008):

$$\begin{aligned} tax_{it} &= \alpha_1 inv_{it} + \alpha_2 tax^{rw}_{it-1} + \alpha_3 X_{it} + \varepsilon_i + \epsilon_{it} \\ inv_{it} &= \beta_1 tax_{it} + \beta_2 inv^{rw}_{it-1} + \beta_3 X_{it} + \upsilon_i + \mu_{it} \end{aligned} \tag{21}$$

Both corporate tax rate and public investment are potentially endogenous. The tax rate depends on the level of public investment, but also responds to the tax rate of the rest of the world (tax^{rw}_{it}). It is not our purpose to distinguish if the response to the foreign tax rate is due to competition for profits or for private investment. Public investment depends on the tax rate, but we also allow it to respond to the level of public investment of foreign countries (inv^{rw}_{it}). X_{it} is a vector of control variables.

We estimate each equation separately using instrumental variables estimation. We include the lagged value of the foreign variables to avoid further problems of endogeneity. We can, therefore, treat them as exogenous making our system exactly identified. Each equation has one omitted exogenous variable that is used as instrument for the endogenous variable. For this, the assumptions that the corporate tax rate does not respond to foreign public investment and that public investment does not react to the foreign tax rate are crucial. The corporate tax and public investment of the rest of the world are weighted averages of the variables for all other countries in the sample.

$$tax^{rw}_{it} = \sum_{j=-i} w_{jt} tax^{rw}_{jt}$$

$$inv^{rw}_{it} = \sum_{j=-i} w_{jt} inv^{rw}_{jt}$$

In the reaction functions we include public investment instead of public capital. Firstly because the decision variable of governments is public investment. Secondly, this way we avoid problems of non-stationarity, because both tax rate and public investment are bounded between 0 and 1 and therefore cannot have unit roots. Similarly to Devereux, Lockwood, and Redoano (2008) we do not include lagged dependent variables as we are interested in the long-run coefficients.

4.2 Data

We estimate the policy functions using a panel of 18 OECD countries. The variable corporate tax rate was taken from Michigan World Tax Database and public investment, was taken from Kamps (2006) and expanded with OECD data until 2005. We use three different weights to calculate the variables for the rest of the world: uniform weights (W_1), the openness of the economy (W_2) and the population (W_3). The correlations between the three measures within a country range from 0.80 to 0.95 for both variables. For most countries the corporate tax rate is not a smooth variable: the changes are not frequent and are usually in big jumps. Therefore, in the regressions we use in the HP filter trend.[8] Table A1 in appendix shows some summary statistics of the two key variables.

We use the following control variables: government consumption, the fiscal surplus, the degree of openness, the level of private capital, population growth, a dummy for election year, the % of left wing votes and a dummy if the country joined the EMU2 after 1999. Summary statistics and the source of each variable can be found in table A2 in appendix.

4.3 Estimation

[8]We used a smoothing parameter of 100. Results with the variable in levels are very similar in terms of explanatory variables, but with lower R2.

We estimate the policy functions using IV estimation with fixed effects. Some of the control variables enter the equations lagged to avoid further problems of endogeneity. We also include country time trends. We estimate an unrestricted and a restricted model. The unrestricted model includes all controls. We then remove the non-significant variables and add them as additional controls. We test the under-identification of each equation and, in the case of the restricted models, we perform the Sargan over-identification test. Given that we only have 18 countries, we model the country specific error as fixed effects. [9].

Table 3 and 4 shows the results. All specifications have considerable good fit with an R^2 above 0.65. There are two important results. First there is endogeneity between the corporate tax rate and investment. Each one responds positively to the other, like our model predicted. If public investment increases by 1 percentage point, tax rate goes up by 2% to 5%. The coefficient of the response of public investment to the tax rate ranges from 0.028 to 0.046. For a reduction of 20% of the tax rate, this direct effect implies a reduction of public investment between 0.56% to 0.9%.

The second result is that there is international competition in both tax rate and public investment. Tax rate responds around 0.5% to an increase of 1% in the tax rate of the rest of the world, which is in line with values reported in Devereux, Lockwood, and Redoano (2008). Public investment the coefficient of response to the foreign public investment is between 0.4 and 0.5, but is not significant if we weight the variables by population.

With respect to the control variables, government consumption, fiscal surplus and population growth are significant in both equations. Openness and the EMU dummy is significant in the tax rate equation while private capital is only significant for public investment. The tests on the validity of the instruments suggest that our specification is correct.

[9] This is clearly supported by the Hausman test

Table 3: Estimation results: corporate tax rate

	W1		W2		W3	
	(1)	(2)	(1)	(2)	(1)	(2)
Inv_t	4.568***	4.247***	1.876**	1.935***	5.630**	4.307***
	(3.15)	*(4.36)*	*(2.16)*	*(3.10)*	*(2.42)*	*(2.69)*
Tax^{rw}_{t-1}	0.632***	0.627***	0.503***	0.498***	0.539***	0.558***
	(10.04)	*(10.36)*	*(12.53)*	*(13.01)*	*(6.89)*	*(9.18)*
$Govcons_{t-1}$	0.546***	0.571***	0.400***	0.406***	0.538***	0.562***
	(4.55)	*(4.94)*	*(4.01)*	*(4.12)*	*(3.36)*	*(3.67)*
$Budget_{t-1}$	0.263**	0.211***	0.107	0.099*	0.398**	0.260**
	(2.24)	*(2.79)*	*(1.39)*	*(1.78)*	*(2.28)*	*(2.55)*
$Open_{t-1}$	-0.055*	-0.03	-0.046**	-0.02	-0.046	-0.032
	(-1.84)	*(-1.04)*	*(-1.98)*	*(-0.89)*	*(-1.23)*	*(-1.07)*
K_{t-1}	1.478		-0.466		4.23	
	(0.65)		*(-0.30)*		*(1.22)*	
$Popg_t$	-2.262***	-2.147***	-1.606***	-1.481***	-2.480***	-2.175***
	(-3.96)	*(-4.15)*	*(-3.81)*	*(-3.68)*	*(-3.07)*	*(-3.13)*
$Election_t$	-0.093		-0.048		-0.183	
	(-0.31)		*(-0.20)*		*(-0.53)*	
$Left_t$	0.150***	0.157***	0.102***	0.116***	0.169***	0.159***
	(3.47)	*(4.09)*	*(3.18)*	*(3.82)*	*(2.95)*	*(3.54)*
Emu_t	-1.609*	-1.965**	-1.305*	-1.572**	-1.937*	-2.222**
	(-1.85)	*(-2.26)*	*(-1.90)*	*(-2.23)*	*(-1.94)*	*(-2.44)*
Country trends	Yes	Yes	Yes	Yes	Yes	Yes
Observations	687	687	687	687	687	687
Countries	18	18	18	18	18	18
R^2	0.64	0.66	0.78	0.78	0.54	0.65
Underidentification test #	18.17 [0.000]	34.25 [0.000]	31.08 [0.000]	53.18 [0.000]	9.06 [0.003]	13.09 [0.000]
Sargan test $	-	0.124 [0.940]	-	0.910 [0.635]	-	0.417 [0.812]
Hausman test &	-	4825.7 [0.000]	60994.8 [0.000]	-	1656.7 [0.000]	4232.3 [0.000]

Notes: Instrumental Variables fixed effects estimation. In columns (1) the equation is exactly identify with inv^{rw}_t as instrument for inv_t . In columns (2) the non-significant variables are excluded from the equation but added as additional instruments. The t statistics are in parentheses. *, **, *** - statistically significant at the 10, 5, and 1 per cent.

[#] The underidentification test is an LM test of whether the instruments are correlated with the endogenous regressors. The null hypothesis that the equation is underidentified. The test statistic is to be compared to a chi-square with degrees of freedom equal to the number of instruments. The p-value is in brackets.

[$] The null hypothesis of the Sargan overidentification test is that the instruments are uncorrelated with the error term and that the excluded instruments are correctly excluded from the estimated equation. Under the null, the test statistic is distributed as chi-squared in the number of overidentifying restrictions. The p-value is in brackets.

[&] The null is that random effects estimation is consistent and therefore preferable to fixed effects. The test statistic is to be compared to a chi-square with the number of degrees of freedom equal the number of regressors (explanatory variables plus 18). The p-value is in brackets.

Table 4: Estimation results: public investment

	W1		W2		W3	
	(1)	(2)	(1)	(2)	(1)	(2)
Tax_t	0.033***	0.035**	0.028*	0.030**	0.046***	0.045***
	(2.19)	*(2.50)*	*(1.94)*	*(2.27)*	*(2.55)*	*(3.37)*
Inv_{t-1}^{rw}	0.504***	0.513***	0.443***	0.445***	0.066	
	(4.84)	*(5.00)*	*(5.62)*	*(5.71)*	*(0.42)*	
$Govcons_{t-1}$	-0.063***	-0.066***	-0.074***	-0.077***	-0.061***	-0.064***
	(-2.77)	*(-2.97)*	*(-3.33)*	*(-3.52)*	*(-2.61)*	*(-2.91)*
$Budget_{t-1}$	-0.066***	-0.065***	-0.067***	-0.066***	-0.069***	-0.066***
	(-6.88)	*(-6.92)*	*(-7.03)*	*(-7.09)*	*(-6.89)*	*(-6.85)*
$Open_{t-1}$	-0.001		-0.004		-0.004	
	(-0.17)		*(-0.89)*		*(-0.80)*	
K_{t-1}	-0.873***	-0.863***	-0.844***	-0.807***	-1.189***	-1.197***
	(-3.79)	*(-3.83)*	*(-3.73)*	*(-3.61)*	*(-4.99)*	*(-5.45)*
$Popg_t$	0.316***	0.325***	0.329***	0.342***	0.326***	0.338***
	(4.09)	*(4.23)*	*(4.31)*	*(4.50)*	*(4.06)*	*(4.34)*
$Election_t$	0.016		0.014		0.022	
	(0.33)		*(0.28)*		*(0.45)*	
$Left_t$	-0.019***	-0.020***	-0.019***	-0.020***	-0.021***	-0.022***
	(-3.22)	*(-3.36)*	*(-3.22)*	*(-3.42)*	*(-3.34)*	*(-3.67)*
Emu_t	0.062		0.041		0.179	
	(0.43)		*(0.28)*		*(1.22)*	
Country trends	Yes	Yes	Yes	Yes	Yes	Yes
Observations	687	688	687	688	687	688
Countries	18	18	18	18	18	18
R^2	0.67	0.67	0.67	0.67	0.65	0.65
Underidentification test [#]	156.43 [0.000]	177.62 [0.000]	164.07 [0.000]	186.49 [0.000]	124.32 [0.003]	203.61 [0.000]
Sargan Test [$]	-	1.482 [0.687]	-	3.116 [0.374]	-	5.355 [0.253]
Hausman [&]	659.5 [0.000]	1116.5 [0.000]	675.4 [0.000]	1100.6 [0.000]	599.0 [0.000]	932.6 [0.000]

Notes: Instrumental Variables fixed effects estimation. In columns (1) the equation is exactly identify with tax_t^{rw} as instrument for tax_t In columns (2) the non-significant variables are excluded from the equation but added as additional instruments. The t statistics are in parentheses. *, **, *** - statistically significant at the 10, 5, and 1 per cent.

[#] The underidentification test is an LM test of whether the instruments are correlated with the endogenous regressors. The null hypothesis that the equation is underidentified. The test statistic is to be compared to a chi-square with degrees of freedom equal to the number of instruments. The p-value is in brackets.

[$] The null hypothesis of the Sargan overidentification test is that the instruments are uncorrelated with the error term and that the excluded instruments are correctly excluded from the estimated equation. Under the null, the test statistic is distributed as chi-squared in the number of overidentifying restrictions. The p-value is in brackets.

[&] The null is that random effects estimation is consistent and therefore preferable to fixed effects. The test statistic is to be compared to a chi-square with the number of degrees of freedom equal the number of regressors (explanatory variables plus 18). The p-value is in brackets.

4.4 Alternative specification

Given these results we attempt a second specification that includes an interaction term between the foreign variables and the level of openness of the economy. The level of openness can be seen as a proxy for globalization. If the coefficient is positive it means that competition has increased with globalization.

$$\begin{aligned} tax_{it} &= \alpha_1 inv_{it} + \alpha_2 tax^{rw}_{it-1} + \alpha_3 tax^{rw}_{it-1} \times Open_{t-1} + \alpha_4 X_{it} + \varepsilon_i + \epsilon_{it} \\ inv_{it} &= \beta_1 tax_{it} + \beta_2 inv^{rw}_{it-1} + \beta_3 inv^{rw}_{it-1} \times Open_{t-1} + \beta_4 X_{it} + \upsilon_i + \mu_{it} \end{aligned}$$

The results are shown in Table 5 and 6. All results from the original specification are robust. The coefficients are of the same order of magnitude. Although the interaction coefficient is not significant in the public investment equation, it is positive and significant in the tax rate equation. The overall response of the tax rate to the foreign tax rate depends on the degree of openness of the economy. In 2004, openness varied from around 25% in US and Japan to 160% in Belgium. These values imply that the final response to foreign tax rate is different across countries, ranging from 0.5 to 1.1. It also implies that in the majority of the OECD countries, the response to the foreign tax rate has increased over time.

Table 5: Estimation results: corporate tax rate (alternative specification)

	W1		W2		W3	
	(1)	(2)	(1)	(2)	(1)	(2)
Inv_t	4.653***	4.413***	2.147**	2.190***	5.026**	4.602***
	(3.21)	*(4.50)*	*(2.46)*	*(3.49)*	*(2.22)*	*(2.88)*
Tax_{t-1}^{rw}	0.339***	0.380***	0.359***	0.375***	0.325***	0.358***
	(3.28)	*(3.68)*	*(5.54)*	*(5.80)*	*(3.43)*	*(3.86)*
$Tax_{t-1}^{rw} \times Open_{t-1}$	0.0055***	0.0046***	0.0028***	0.0024**	0.0046***	0.0040**
	(3.58)	*(3.04)*	*(2.79)*	*(2.34)*	*(2.71)*	*(2.55)*
$Govcons_{t-1}$	0.464***	0.502***	0.356***	0.371***	0.410**	0.479***
	(3.79)	*(4.18)*	*(3.46)*	*(3.63)*	*(2.47)*	*(2.83)*
$Budget_{t-1}$	0.295**	0.246***	0.137*	0.126**	0.374**	0.296***
	(2.52)	*(3.21)*	*(1.77)*	*(2.23)*	*(2.25)*	*(2.95)*
$Open_{t-1}$	-0.267***	-0.213***	-0.152***	-0.112**	-0.237***	-0.196***
	(-4.01)	*(-3.19)*	*(-3.36)*	*(-2.44)*	*(-2.82)*	*(-2.64)*
K_{t-1}	1.299		-0.461		2.934	
	(0.57)		*(-0.29)*		*(0.86)*	
$Popg_t$	-2.187***	-2.125***	-1.643***	-1.531***	-2.244***	-2.211***
	(-3.82)	*(-4.05)*	*(-3.85)*	*(-3.76)*	*(-2.86)*	*(-3.12)*
$Election_t$	-0.093		-0.048		-0.151	
	(-0.31)		*(-0.20)*		*(-0.47)*	
$Left_t$	0.167***	0.174***	0.116***	0.130***	0.174***	0.179***
	(3.86)	*(4.48)*	*(3.56)*	*(4.18)*	*(3.30)*	*(3.99)*
Emu_t	-0.97	-1.467	-0.989	-1.345*	-1.286	-1.779*
	(-1.09)	*(-1.64)*	*(-1.40)*	*(-1.86)*	*(-1.31)*	*(-1.83)*
Country trends	Yes	Yes	Yes	Yes	Yes	Yes
Observations	687	687	687	687	687	687
Countries	18	18	18	18	18	18
R^2	0.64	0.66	0.78	0.78	0.54	0.65
Underidentification test [#]	18.19 [0.000]	34.60 [0.000]	31.56 [0.000]	54.52 [0.000]	8.29 [0.004]	14.04 [0.000]
Sargan Test [$]	-	0.348 [0.840]	-	1.222 [0.543]	-	0.094 [0.954]
Hausman [&]	-	4162.0 [0.000]	30180.9 [0.000]	-	-	-

Notes: Instrumental Variables fixed effects estimation. In columns (1) the equation is exactly identify with inv_t^{rw} as instrument for inv_t . In columns (2) the non-significant variables are excluded from the equation but added as additional instruments. The t statistics are in parentheses. *, **, *** - statistically significant at the 10, 5, and 1 per cent.

[#] The underidentification test is an LM test of whether the instruments are correlated with the endogenous regressors. The null hypothesis that the equation is underidentified. The test statistic is to be compared to a chi-square with degrees of freedom equal to the number of instruments. The p-value is in brackets.

[$] The null hypothesis of the Sargan overidentification test is that the instruments are uncorrelated with the error term and that the excluded instruments are correctly excluded from the estimated equation. Under the null, the test statistic is distributed as chi-squared in the number of overidentifying restrictions. The p-value is in brackets.

[&] The null is that random effects estimation is consistent and therefore preferable to fixed effects. The test statistic is to be compared to a chi-square with the number of degrees of freedom equal the number of regressors (explanatory variables plus 18). The p-value is in brackets.

Table 6: Estimation results: public investment (alternative specification)

	W1		W2		W3	
	(1)	(2)	(1)	(2)	(1)	(2)
Tax_t	0.033**	0.035**	0.029**	0.030**	0.047***	0.045***
	(2.19)	*(2.50)*	*(2.00)*	*(2.27)*	*(2.58)*	*(3.37)*
Inv_{t-1}^{rw}	0.496***	0.513***	0.384***	0.445***	0.102	
	(3.65)	*(5.00)*	*(3.40)*	*(5.71)*	*(0.63)*	
$Inv_{t-1}^{rw} \times Open_{t-1}$	0.0002		0.0012		-0.0009	
	(0.09)		*(0.72)*		*(-0.50)*	
$Govcons_{t-1}$	-0.063***	-0.066***	-0.076***	-0.077***	-0.062***	-0.064***
	(-2.77)	*(-2.97)*	*(-3.42)*	*(-3.52)*	*(-2.68)*	*(-2.91)*
$Budget_{t-1}$	-0.066***	-0.065***	-0.067***	-0.066***	-0.069***	-0.066***
	(-6.87)	*(-6.92)*	*(-7.01)*	*(-7.09)*	*(-6.89)*	*(-6.85)*
$Open_{t-1}$	-0.001		-0.007		-0.002	
	(-0.18)		*(-1.15)*		*(-0.28)*	
K_{t-1}	-0.873***	-0.863***	-0.848***	-0.807***	-1.193***	-1.197***
	(-3.79)	*(-3.83)*	*(-3.74)*	*(-3.61)*	*(-4.99)*	*(-5.45)*
$Popg_t$	0.317***	0.325***	0.330***	0.342***	0.326***	0.338***
	(4.09)	*(4.23)*	*(4.33)*	*(4.50)*	*(4.06)*	*(4.34)*
$Election_t$	0.016		0.015		0.021	
	(0.34)		*(0.32)*		*(0.43)*	
$Left_t$	-0.019***	-0.020***	-0.019***	-0.020***	-0.021***	-0.022***
	(-3.22)	*(-3.36)*	*(-3.24)*	*(-3.42)*	*(-3.29)*	*(-3.67)*
Emu_t	0.062		0.035		0.189	
	(0.42)		*(0.24)*		*(1.29)*	
Country trends	Yes	Yes	Yes	Yes	Yes	Yes
Observations	687	688	687	688	687	688
Countries	18	18	18	18	18	18
R^2	0.67	0.67	0.67	0.67	0.65	0.65
Underidentification test #	156.02 [0.000]	177.62 [0.000]	165.01 [0.000]	186.49 [0.000]	127.14 [0.000]	203.60 [0.000]
Sargan test $	-	1.482 [0.687]	-	3.116 [0.374]	-	5.355 [0.253]
Hausman test &	626.5 [0.000]	1116.5 [0.000]	633.7 [0.000]	1100.6 [0.000]	566.9 [0.000]	932.6 [0.000]

Notes: Instrumental Variables fixed effects estimation. In columns (1) the equation is exactly identify with tax_t^{rw} as instrument for tax_t In columns (2) the non-significant variables are excluded from the equation but added as additional instruments. The t statistics are in parentheses. *, **, *** - statistically significant at the 10, 5, and 1 per cent.

The underidentification test is an LM test of whether the instruments are correlated with the endogenous regressors. The null hypothesis that the equation is underidentified. The test statistic is to be compared to a chi-square with degrees of freedom equal to the number of instruments. The p-value is in brackets.

$ The null hypothesis of the Sargan overidentification test is that the instruments are uncorrelated with the error term and that the excluded instruments are correctly excluded from the estimated equation. Under the null, the test statistic is distributed as chi-squared in the number of overidentifying restrictions. The p-value is in brackets.

& The null is that random effects estimation is consistent and therefore preferable to fixed effects. The test statistic is to be compared to a chi-square with the number of degrees of freedom equal the number of regressors (explanatory variables plus 18). The p-value is in brackets.

5 Concluding Remarks

Globalization represents a challenge for governments which have to choose between two alternatives. Decision makers can either endorse the competition by focusing their action on productive purposes or they can decide to protect their constituency by using public finance for "compensation". The impressive downward trend of statutory corporate tax rates represents one of the most striking aspects of international competition between governments and for this reason our paper tries to shed light on this crucial issue.

Keen and Marchand (1997) pointed out that tax competition might lead to *"too many business centers and airports but not enough parks or libraries"*. In fact, this statement might be inconsistent with the general decline of public capital stock that has taken place over the last two decades among many OECD countries. By contrast, we find a positive relationship between corporate tax rates and public capital stock. The robustness analysis we performed provides a strong evidence that the central mechanism of our paper remains. Besides, this link appears to be significant for most countries where the share of public capital stock has indeed decreased.

The general equilibrium analysis appears to be extremely helpful when we want to assess the effect of competition. We show that tax competition leads to a reduction of both tax rate and public investment. If tax rate goes down by 20%, public investment goes down by 0.4% of GDP. Our empirical estimates point to slightly higher values: between 0.5% and 0.9% of GDP. Further empirical evidence indicates that there is international competition in both corporate tax rate and public investment and that the corporate tax rate competition increases with the level of openness of an economy.

Although tax competition is likely to have a negative effect on public consumption, the traditional view considers that tax competition favours the private sector. This is indeed what we found in the baseline scenario and it is explained by the fact that a race to the bottom reduces the net cost of capital. But the government does not only maximize tax revenue but also provides to the households and the private sector essential public goods.

Departing from this baseline calibration by considering a stronger impact of public capital on the production process, we found that it could exist a threshold tax rate under which tax competition has a negative effect on total output. This could be the case in countries where public/private capital substitutability is not very strong, when the production process relies heavily on human capital or general infrastructure.

We believe that our analysis is particularly relevant for European Union countries where enlargement is likely to put more pressure on tax rates and therefore could reinforce the downward trend of public capital stock in Western European countries. It could indeed represent an issue since public infrastructures and public capital in general are likely to have crucial impact on countries' performance in respecting the Lisbon strategy. This could be a real challenge for the next years: if more tax competition does not shift the focus of public spending on productive purposes, how can Europe achieve its strategy and become a highly competitive and knowledge-based economy. Under theses circumstances, a traditional public policy implication would be to control tax competition. However a tax harmonization scheme is likely to fail for political economic reasons. Another possibility would be to affect directly the allocation of public resources. The central mechanism of our model emerges because countries decide non-cooperatively. Therefore some common actions are needed: in fact, the Lisbon agenda and the open method of coordination represent small steps in this direction.

Appendix 1: The General Equilibrium Model

These are the general equations evaluated at the steady state:

- The household:

$1 + r = \frac{1}{\beta}$

$I^i = \delta B^i$

- The multinational firm:

$y^i = (k^i)^\alpha (P^i)^\theta$

$k^i = (P^i)^{\frac{\theta}{1-\alpha}} \left[\frac{r}{\alpha(1-\tau^i)} + \frac{\delta}{\alpha}\right]^{\frac{1}{\alpha-1}}$

$s = \frac{\tau^A - \tau^B}{2b}$

$w^i = y^i(1 - \alpha - \theta)$

- The governments:

$$g^i + p^i = \bar{t} + \tau^i \left[y^i - \delta k^i - w^i \pm s\right]$$

$$p^i = \delta_p P^i$$

$$\frac{\tau^A}{b} = \frac{\tau^B}{2b} - \left(P^A\right)^{\theta/(1-\alpha)} \left[\frac{r}{\alpha(1-\tau^A)} + \frac{\delta}{\alpha}\right]^{\frac{1}{\alpha-1}} \left\{\frac{\tau^A r^2}{(\tau^A-1)^2(\alpha-1)[(\tau^A-1)\delta-r]} + \frac{(\tau^A-1)(\alpha-1)\delta+r}{\alpha(\tau^A-1)}\right\}$$

$$\frac{\tau^B}{b} = \frac{\tau^A}{2b} - \left(P^B\right)^{\theta/(1-\alpha)} \left[\frac{r}{\alpha(1-\tau^B)} + \frac{\delta}{\alpha}\right]^{\frac{1}{\alpha-1}} \left\{\frac{\tau^B r^2}{(\tau^B-1)^2(\alpha-1)[(\tau^B-1)\delta-r]} + \frac{(\tau_t^B-1)(\alpha-1)\delta+r}{\alpha(\tau^B-1)}\right\}$$

$$\frac{\theta}{1-\alpha}(P^i)^{\frac{\theta+\alpha-1}{1-\alpha}} \tau^i \left(\frac{r}{\alpha(1-\tau^i)} + \frac{\delta}{\alpha}\right)^{\frac{1}{\alpha-1}} \left[\frac{r+\delta(1-\alpha)(1-\tau^i)}{\alpha(1-\tau^i)}\right] = \frac{1}{\beta} + \frac{\gamma}{\xi}\frac{g^i}{P^i} - 1 + \delta_p$$

- Market Clearing:

$$B^A + B^B = k^A + k^B$$

$$y^A + y^B = c^A + c^B + g^A + g^B + p^A + p^B + I^A + I^B + bs^2$$

$$c^A + I^A = w^A + rb^A - \bar{t} + [(1-\tau^A)(y^A - w^A - \delta k^A - s) - rk^A]$$

Appendix 2

Table 7: Descriptive statistics on corporate tax rates and public investment

	Tax (HP filter)				Public Investment		
	Mean	Max	Min		Mean	Max	Min
Australia	40.9	46.0$_{(1982)}$	29.2$_{(2005)}$	Australia	3.09	4.46$_{(1966)}$	2.32$_{(1988)}$
Austria	42.7	54.6$_{(1981)}$	28.4$_{(2006)}$	Austria	3.81	5.92$_{(1972)}$	1.14$_{(2006)}$
Belgium	39.3	47.2$_{(1981)}$	31.3$_{(1967)}$	Belgium	2.45	4.65$_{(1980)}$	1.48$_{(2003)}$
Denmark	38	45.1$_{(1962)}$	27.9$_{(2006)}$	Denmark	3.11	5.64$_{(1970)}$	1.49$_{(1991)}$
Finland	36.4	45.0$_{(1968)}$	25.9$_{(1994)}$	Finland	3.09	4.14$_{(1968)}$	1.87$_{(1961)}$
France	43.5	50.5$_{(1977)}$	32.8$_{(1999)}$	France	3.38	4.23$_{(1965)}$	2.73$_{(1984)}$
Germany	46.8	56.4$_{(1983)}$	22.9$_{(2006)}$	Germany	3.00	4.74$_{(1964)}$	1.57$_{(2005)}$
Greece	39.1	47.3$_{(1986)}$	31.6$_{(2006)}$	Greece	3.38	5.13$_{(1962)}$	1.87$_{(1980)}$
Ireland	36.6	48.9$_{(1985)}$	9.51$_{(2006)}$	Ireland	4.39	7.19$_{(1974)}$	2.08$_{(1988)}$
Italy	27.7	36.8$_{(1995)}$	14.3$_{(1960)}$	Italy	2.87	3.81$_{(1966)}$	1.68$_{(2002)}$
Japan	37.2	42.1$_{(1984)}$	28.8$_{(2006)}$	Japan	7.65	10.1$_{(1978)}$	4.20$_{(2006)}$
Netherlands	41.7	47.9$_{(1977)}$	31.8$_{(2006)}$	Netherlands	4.18	7.10$_{(1968)}$	2.79$_{(1989)}$
New Zealand	40.1	45.8$_{(1973)}$	32.6$_{(1999)}$	New Zealand	4.86	8.15$_{(1975)}$	2.37$_{(1993)}$
Norway	28.2	30.1$_{(1960)}$	27.4$_{(1976)}$	Norway	3.49	4.48$_{(1972)}$	2.80$_{(1985)}$
Spain	33.7	35.0$_{(1995)}$	29.3$_{(1965)}$	Spain	3.10	4.82$_{(1990)}$	1.65$_{(1979)}$
Sweden	37.3	44.4$_{(1986)}$	27.3$_{(2002)}$	Sweden	2.49	3.33$_{(1968)}$	1.92$_{(1987)}$
UK	37.7	54.7$_{(1978)}$	29.6$_{(2006)}$	UK	2.68	4.66$_{(1968)}$	0.77$_{(2005)}$
US	42.8	51.8$_{(1960)}$	34.5$_{(1996)}$	US	3.50	4.96$_{(1961)}$	2.66$_{(1977)}$
$Tax^{rw}(W_1)$	37.6-38.8	44.1-44.9	28.5-29.7	$Inv^{rw}(W_1)$	3.29-3.57	4.17-4.52	2.56-2.76
$Tax^{rw}(W_2)$	36.2-37.5	44.0-45.8	28.3-30.0	$Inv^{rw}(W_2)$	3.34-3.54	4.29-4.70	2.51-2.71
$Tax^{rw}(W_3)$	36.6-39.8	44.4-46.4	29.6-32.1	$Inv^{rw}(W_3)$	3.23-4.11	4.17-5.08	2.74-3.19

Table 8: Sources

Variable	Description	Mean	Sd	Max	Min	Source
Inv	Public investment (% GDP)	3.499	1.504	10.09	0.770	Kamps (2006)
Tax	Top bracket corporate tax	38.21	8.730	56.41	7.148	Michigan World Tax Database
Govcons	Government consumption (% GDP)	17.66	4.511	30.14	7.325	OECD-Main Economic Indicators
Budget	Budget surplus (% GDP)	-2.212	3.851	18.00	-15.71	IMF- International Financial Stat
Popg	Population growth	0.660	0.569	3.799	-4.526	World Bank World Development Indicators
Open	Openness (% GDP)	54.77	29.29	184.2	7.416	World Bank World Development Indicators
Capital	Private capital (% GDP)	2.512	0.541	3.818	1.255	Kamps (2006)
Left	Left party votes (% total)	37.96	14.15	67.6	0	Swank
Election	Dummy for election year	0.316	0.465	1	0	Swank

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