Do Countries Compete over Corporate Tax Rates?*

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First version: May 2001
This version: December 2002

Abstract

This paper tests whether OECD countries compete with each other over corporate taxes in order to attract investment. We develop two models: with firm mobility, countries compete only over the statutory tax rate or the effective average tax rate, while with capital mobility, countries compete only over the effective marginal tax rate. We estimate the parameters of reaction functions using data from 21 countries between 1983 and 1999. We find evidence that countries compete over all three measures, but particularly over the statutory tax rate and the effective average tax rate. This is consistent with a belief amongst governments that location choices by multinational firms are discrete. We also find evidence of concave reaction functions, consistent with the model outlined in the paper.

Keywords: tax competition, corporate taxes, effective average tax rate, effective marginal tax rate.

JEL Classification Numbers: H0, H25, H77

*The research reported here received financial support from the ESRC, and from the CSGR at Warwick University. We would like to thank Rachel Griffith and Lucy Chennells for help in assembling corporate tax data. We would also like to thank participants at the World Tax Competition conference at the IFS, the conference on Strategic Interaction among Local Governments at the Catholic University of Milan, the Workshop on Taxation and Public Debt at the University of Warwick's London Office, and seminar participants at EPRU, University of Copenhagen, and the Universities of Exeter, Edinburgh, Keele, Oslo, Newcastle and Warwick for helpful comments.

1. Introduction

Statutory rates of corporation tax in developed countries have fallen substantially over the last two decades. The average rate amongst OECD countries in the early 1980s was nearly 50%; by 2001 this had fallen to under 35%. In 1992, the European Union's Ruding Committee recommended a minimum rate of 30% - then lower than any rate in Europe (with the exception of a special rate for manufacturing in Ireland). Ten years later, already one third of the members of the European Union have a rate at or below this level. It is commonly believed that the reason for these declining rates is a process of tax competition: countries compete with each other to attract inward flows of capital by reducing their tax rates on corporate profit. Such a belief has led to increasing attempts at international coordination in order to maintain revenue from corporation taxes. Both the European Union and the OECD introduced initiatives in the late 1990s designed to combat what they see as "harmful" tax competition.

The notion that there is increasing competitive pressure on governments to reduce their corporation tax rates has been the subject of a growing theoretical literature - surveyed by Wilson (1999). But there have been no detailed attempts to examine whether there is any empirical evidence of such international competition in taxes on corporate income. In this paper we aim to provide such evidence.

Before turning to evidence, however, it is necessary to expand existing theory, which suffers from three important and related weaknesses. First, the vast majority of existing theory does not adequately deal with the fact that governments have two broad instruments for determining corporate income taxes: the rate and the base. Almost exclusively,[1] theoretical models of tax competition combine these into a single *effective marginal tax rate* (EMTR), which is the tax on the marginal return to capital. For example, in the standard model in the literature, developed by Zodrow and Mieszkowski, 1986 and Wilson, 1986, referred to below as the ZMW model, governments levy taxes on the returns to capital only. But it is easily shown that when the statutory rate and the base of the corporate tax can be set independently, the return to capital and the pure economic rent accruing to the owners of the firm can be also taxed independently. So, a prerequisite for an adequate theory of corporate tax competition is to allow countries to compete in two dimensions, over the rate *and* the base: this requires an extension of the existing

[1] An exception is Haulfer and Schjelderup (2000), in the context of a model which incorporates mobile capital and profit shifting. Competition for shifting mobile tax bases should be over statutory tax rates, which is consistent with our results; however, we do not explore this possibility here.

theory[2].

As second problem that follows immediately is that if the rent accruing to the owner of the firm can be taxed, then as long as the owners are immobile, the corporate tax can be made non-distortionary by allowing full deductibility of capital expenditure - a cash-flow corporate tax. But, in many standard models of tax competition, notably the ZMW model, the owners of the firms *are* assumed immobile[3]. This then raises a problem for the modelling of tax competition: governments will not react to each others' taxes, but simply use the cash-flow corporate tax to finance their expenditures. So an extension of the theory to the case of mobile firms is required.

A third and related point is that in practice, multinational firms make discrete choices as to where to locate.[4] Discrete location choices do not depend on the EMTR. Rather they depend on how taxes affect the post-tax level of profit available in each potential location. In a world of mobile firms, location is determined by the proportion of profit taken in tax, measured by the *effective average tax rate* (EATR). In turn, the underlying parameters of the corporate tax system, the rate and the base, determine both the EMTR and the EATR.

We therefore begin by developing two models which help clarify the nature of corporate tax competition. In the first model, firms are mobile, but countries are small relative to the world capital market. In this case, it is shown that countries compete only in the EATR.[5] In our second model[6], firms are immobile, and countries are large relative to the world capital market. In this case, it is shown that countries compete only in the EMTR. For each of the two models, we derive tax reaction functions, and we pay particular attention to the shape of these reaction functions. Under plausible assumptions, they are concave in the neighborhood of symmetric equilibrium : that is, countries react more strongly to the tax cuts of others when their own taxes are high.

Having developed these two models, we confront them with data, specifically a panel data set

[2] Multiple tax instruments have been studied using the ZMW model e.g. Bucovetsky and Wilson (1991), Huber (1999), but in these contributions, the second tax is a tax on labour.

[3] In the ZMW model, it is usually assumed that there are two classes of agent, workers and capital-owners. The former receive all the rent from production, and are usually assumed internationally immobile.

[4] Models which incorporate discrete location choices are common in the trade literature; see, for example, Horstman and Markusen (1992) and Motta (1992).

[5] This model is related to a variety of other models in which countries compete for foreign direct investments by offering subsidies to firms (Black and Hoyt, 1989, Bond and Samuelson, 1986, King and Welling, 1992, King, McAfee, and Welling, 1993, Haaparanta, 1996, Haufler and Wooton, 1999). However, our focus is on the use of the tax system, rather than the use of subsidies, to induce relocation.

[6] This model is quite closely related to extensions of the basic ZMW model to allow for the elastic supply of the internationally immobile factor of production (usually interpreted as labour), such as Bucovetsky and Wilson, (1991). They find that a "small" region should meet all of its revenue needs by taxing income from the fixed factor, as capital is in perfectly elastic supply. Wilson (1991) argues that when countries are "large" (as in our model), capital should also be taxed, a finding similar to ours.

of 21 OECD countries between 1983 and 1999. Motivated by our theory, we see the key question as being whether there is evidence of interaction between countries in their setting of the EATR or the EMTR, or indeed, both. A secondary question is whether there is evidence of non-linearity, or more specifically, concavity in these reaction functions. Our empirical measures of the EATR and the EMTR are derived from applying the rules of the tax system to a hypothetical investment project (Devereux and Griffith, 2002). These measures have been used for other purposes[7], but not for investigating strategic interactions between countries: this paper is the first, to our knowledge, to estimate tax reaction functions based on detailed measures of corporate taxes.[8]. These measures are time-consuming to construct in that they involve collection of data about parameters of the corporate tax system in each country and each year, as well as considerable calculation. This may be one reason for the lack of progress on this important question to date.

Our findings are as follows. We find evidence consistent with our prediction (under the assumption of mobile firms) that countries compete over the statutory tax rate and the EATR. We find rather weaker evidence that countries compete over EMTRs. Our findings are thus consistent with the common belief amongst governments that the typical location decision of a multinational is a mutually exclusive discrete choice between two locations. So, contrary to the vast majority of the theoretical literature, we would argue that the impact of interactions in corporate tax can be measured by the EATR rather than by the EMTR. We also find evidence in favour of the concavity of the reaction functions predicted by the theory. Specifically, we find countries with relatively high tax rates tend to respond more strongly to changes in tax rates in other countries.

Our empirical work builds on a small but growing empirical literature on strategic interaction between fiscal authorities, initiated by a pioneering study by Case, Rosen and Hines (1993), who estimated an empirical model of strategic interaction in expenditures among state governments in the US. Apart from the careful examination of the form of tax rate, our approach extends this literature in two ways. First, existing empirical work on tax reaction functions has employed data on local (business) property tax rates (Brueckner, 1998, Brett and Pinkse, 2000, Heyndels and Vuchelen, 1998), or on local or state income taxes (Besley and Case, 1995, Heyndels and Vuchelen, 1998). This is significant, because, while local property taxes may determine

[7] For example, constructed measures of the EMTR have been used elsewhere to make international comparisons of corporate income taxes (see, for example, King and Fullerton (1984), OECD (1991), Devereux and Pearson (1995), Chennells and Griffith (1997), European Commission (2001)). Devereux and Freeman (1995) provide evidence that flows of foreign direct investment depend on differences in the EMTR across countries. Devereux and Griffith (1998) provide evidence that the discrete location choices of US multinationals depend on differences in the EATR.

[8] Altshuler and Goodspeed (2002) and Besley et al (2001) include corporate taxes in more general empirical studies of tax competition. However, their measures are based on tax revenue data, which do not provide a good measure of incentives, either for marginal or discrete investment decisions.

business location within a region, corporate taxes are the most obvious taxes in determining location of investment between countries. Our study is therefore the first to test whether there is *national-level* competition through taxes to attract investment.

Second, our empirical approach to estimating tax reaction functions also differs somewhat from the Case-Rosen-Hines methodology followed closely by many other papers. First, based on the models we develop, as noted above we allow reaction functions to be non-linear. Second, we allow tax reaction functions to be dynamic. This has two aspects. First, we suppose that there is some cost to changing tax rates, which generates less than instant adjustment to the new equilibrium level - this implies a role for the lagged dependent variable. Second, we also allow for the possibility that governments respond to lagged values of other countries' tax rates, instead of only the contemporaneous rates.

Of course, it is possible that strategic interaction in tax setting may also be due to electoral or yardstick competition, as opposed to tax competition. The latter occurs when voters in any tax jurisdiction use the taxes (and expenditures) set by their own political representative relative to those in neighboring jurisdictions to evaluate the performance of their representative (Besley and Case (1995), Besley and Smart (2001) Bordignon, Cerniglia, and Revelli (2001)). A standard method for testing for yardstick competition is to estimate a "popularity equation", relating the share of the vote obtained by the incumbent in the last election (or alternatively, a dummy recording whether the incumbent won the election) to the tax in that jurisdiction, and taxes in "neighboring" jurisdictions. We do not follow this approach here, for two reasons. First, we believe that there is a prima facie case that yardstick competition in corporate tax rates is unlikely. The corporate tax system is complex and does not directly affect voters (as opposed to say, income or indirect taxes), so it is simply not a salient issue for them when voting. Second, there is evidence that corporate taxes do affect FDI flows and location decisions of multinationals. Moreover, governments are aware of this evidence, and are clearly concerned about the mobility of the corporate tax base.

The layout of the rest of the paper is as follows. Section 2 provides a theoretical framework for the empirical analysis. Section 3 discusses several issues in the empirical implementation of these models. Section 4 presents the data. Section 5 discusses further econometric issues, and Section 6 presents the results. Section 7 briefly concludes.

2. A Theoretical Framework

2.1. A Model of Corporate Tax Competition

The objectives of our theoretical modeling are first, to understand the forces that generate competition between countries in statutory tax rates, EATRs, and EMTRs, and secondly, to generate some testable predictions. Our model builds on the well-known Zodrow-Mieszkowski-Wilson (ZMW) model (Zodrow and Mieszkowski, 1986, Wilson, 1986), and also extends the existing literature on this model in several novel directions.

2.1.1. Preliminaries

There are two countries $i = 1, 2$. Each country has a unit measure of capitalists, who each own an endowment of capital, κ, and a unit measure of entrepreneurs, each of whom owns a production technology (a firm). A firm can produce a private consumption good, using capital and entrepreneurial effort. A firm located in either country can produce output $F(k, e)$, where k is a capital input, and e is entrepreneurial effort[9]. We assume that $e \in \{0, 1\}$, and that the cost of effort to the entrepreneur is ψe. The production function has the usual properties (strictly increasing in both arguments, and strictly concave). The price of the capital input is denoted by r, and is determined as described below.

Every agent resident in country i has utility over consumption of the private good (denoted by x) and of a public good (denoted by g) of the quasi-linear form :

$$u(x, g) = x + v(g) \tag{2.1}$$

where the function v is increasing and concave. One unit of the private consumption good can be transformed into one unit of the public good. Governments finance the provision of a public good though a corporate tax, described in more detail below. Each government chooses the parameters of the corporate tax system to maximise the sum of utilities of the residents of the country, taking as given the tax system in the other country.

The mobility assumptions are the following. Capital is perfectly mobile between countries. Entrepreneurs are assumed mobile between countries, but at a cost. An entrepreneur resident in country i can move to country j, but at a relocation cost[10] c. In each country, the distribution of these relocation costs is distributed on $[\underline{c}, \overline{c}]$ with distribution function H.

[9] The role of entrepreneurial effort is explained in more detail in Section 2.3.

[10] For simplicity, it is assumed that these costs cannot be deducted from taxable profit e.g. they are psychcic costs.

The order of events is as follows.

1. Governments in both countries choose their corporate tax systems.
2. Capitalists make investment decisions, and entrepreneurs make relocation decisions (if any).
3. Entrepreneurs purchase capital inputs and choose effort.
4. Production and consumption take place.

We solve the model backwards, introducing additional formal notation as required. Of course, our main focus of interest is what happens at stage 1.

The above model is a variant of the ZMW model with two new features. First, firms are allowed to be mobile. This is required to generate competition between countries in EATRs. Second, we introduce a second input, entrepreneurial effort. Without this feature, then in the case of immobile firms, the government in either country could use corporation tax to tax the rents (the profits from firms) without causing any distortions. Consequently, the desired level of public good provision could be optimally financed first by taxing rents, and then, when rents are exhausted, by taxing capital[11]. So, without some upper bound on the statutory rate, a country would set a positive EMTR only when the statutory tax is at 100%. But when the statutory tax is at 100%, the EMTR is not in fact well-defined[12]. This problem could be eliminated in an ad hoc way simply by imposing an upper bound on τ. However, we present a relatively simple way of deriving an upper bound on τ endogenously, by allowing the rent of the firm to depend on variable entrepreneurial effort.

2.1.2. The Corporate Tax System

We begin by describing the corporate tax system and its effect on the firm. Consider a firm producing output $F(k, e)$. The tax paid by the firm is $\tau(F(k, e) - ark)$, where $0 \leq \tau \leq 1$ is the statutory rate of tax, and $a \geq 0$ is the rate of allowance. In the case of equity finance, a is the percentage of investment deductible from profit. However, a can also reflect the benefits of interest deductibility in the presence of debt-financed investment. Note that a cash flow tax

[11] The latter case would only arise when demand for public goods were high enough.

[12] To see this, note that $m = \tau(1 - a)/(1 - \tau)$, so if $\tau = 1$, $m = \infty$, whatever a, using the notation of Section 2.1.2. This can be finessed by imposing an upper bound of $1 - \varepsilon$ on τ, where ε is very small, but of course, the ε is arbitrary.

would imply that $a = 1$ (all investment costs are deductible, but interest payments are not). To allow for debt finance, we do not impose $a \leq 1$. Post-tax profit is:

$$\pi = F(k, e) - rk - \tau (F(k, e) - ark). \tag{2.2}$$

The firm chooses capital to maximise after-tax profit, which from (2.2) gives the following condition:

$$F_k(k, e) = (1 + m)r, \; m = \frac{\tau(1 - a)}{(1 - \tau)}. \tag{2.3}$$

Hence m is the effective marginal tax rate (EMTR) on new investment[13]. Consequently, m is the "dimension" of the tax system that determines the scale of a firm's operation i.e. the choice of k, in any country, other things equal. Note that with a cash flow tax, $m = 0$.

Now note from (2.2) that the firm's after-tax profit in a country with tax system (τ, a) can be written

$$\pi = [1 - \lambda] (F(k, e) - rk), \; \lambda = \frac{\tau (F(k, e) - ark)}{F(k, e) - rk}.$$

Hence λ is the effective average tax rate (EATR) i.e. tax paid as a percentage of true economic profit. Consequently, λ is the "dimension" of the tax system that determines the location of the firm, other things equal. Note that with a cash-flow tax, $\lambda = \tau$.

To summarise, a corporate tax system with underlying tax parameters (τ, a) generates two different effective tax rates, the EATR and the EMTR, which help determine the location decision of the firms and the investment decision of the firm respectively.

2.1.3. Classification of Different Cases and Overview of Results

We can now consider different variants of the model, which generate competition in different "dimensions" of the tax system. Say that the two countries *react only in statutory rates* if the optimal choice of τ_1 depends on τ_2, and vice versa, and a_1 is independent of a_2, τ_2, and vice versa. Conversely, say that the two countries *react only in allowances* if the optimal choice of a_1 depends on a_2, and vice versa, and τ_1 is independent of a_2, τ_2, and vice versa. In each of these cases, tax reaction functions are said to be *one-dimensional.* The general case is where (a_1, τ_1) both depend on (a_2, τ_2) and vice versa, in which case tax reaction functions is said to be *two-dimensional.*

We can now identify the assumptions under which we get one- or two-dimensional tax reaction functions. First, note that firms, or more precisely, the entrepreneurs that own them, may be mobile ($\underline{c} \leq \overline{c} < \infty$) or not ($\underline{c} = \overline{c} = \infty$). Second, the price of the capital input may

[13] We discuss the measures used in the empirical work further in Section 4.1. and Appendix B.

be determined in one of two possible ways. First, as in the original ZMW model, each of the two countries may be assumed "small" relative to the size of the capital market, in the sense that they cannot affect r. In this case, we simply take r as fixed. Second, each country may be "large" relative to the capital market[14], so that r is determined endogenously, and will be affected by the taxes (τ_i, a_i) set by the two countries $i = 1, 2$. The dependence of r on the taxes is sometimes known as the *terms-of-trade effect*.

We then have the following results:

Table 1

	Countries small relative to the capital market	*Countries large relative to the capital market*
Immobile firms ($\underline{c}$=$\bar{c}$= ∞)	Original ZMW model: no tax reaction functions	Model 2: reaction functions in allowances only
Mobile firms ($\underline{c}$≤$\bar{c}$< ∞)	Model 1: reaction functions in statutory taxes only	Two-dimensional reaction functions

When countries $i = 1, 2$ are small relative to the capital market and firms are immobile, we have the original ZMW model (modulo the introduction of entrepreneurial effort). In this model, there are no tax reaction functions[15]: each country i chooses (τ_i, a_i) taking r as fixed, and so does not react to taxes set in other countries. When r is fixed but firms are mobile, we have Model 1. Here, it is shown that a cash-flow tax ($a_i = 1$) is *always* optimal for any country, whatever the corporate tax system of the other. So, by the above definition, countries compete only in statutory tax rates: they use their statutory tax rates to compete for the inward location of firms.

Model 2 is the mirror image of model 1. Here, there is no competition in statutory taxes, as they cannot affect the price of capital. In fact, statutory taxes are set to extract the maximum rent from entrepreneurs, whilst inducing them to supply positive effort. Given the statutory tax fixed, countries then set their allowances to manipulate the demand for capital, and thus the price of capital. So, countries compete in only allowances, or equivalently in EMTRs.

The most general case is where firms are mobile and countries are "large". In this case, there will generally be competition both in τ and a i.e. the choice of τ_1 and a_1 will depend on

[14] Following e.g. Brueckner(2000), this is modelled by supposing that the entrepreneurs and capitalists of the two countries are the only agents transacting on the capital market.

[15] This may sound paradoxical, given that the ZMW model is usually taken to be the canonical model of tax competition. However, from a formal point of view, it is true (and is shown in Section 2.3 below) that the tax choices of country 1 are *independent* of country 2, and vice versa, when r is fixed. What is called "competition" in the ZMW model is in reality, nothing more than the fact that with capital mobility, the supply of capital in any particular country becomes elastic, with the implication that the optimal tax on capital is lower than it is in the closed economy.

both τ_2 and a_2. We now formally demonstrate the claimed properties of Models 1 and 2, and also derive specific results on the shape of the reaction functions in each case.

2.2. Corporate Tax Competition when Firms are Mobile

Here, to avoid analysis of awkward corner solutions, we suppose that $\underline{c}= 0$, so the distribution H of relocation costs is on support $[0, \overline{c}]$. Then, if the tax systems of the two countries are not too different, there will be an entrepreneur of type $0 < \hat{c} < \overline{c}$ in either country 1 or 2 that is indifferent about where he locates: we assume that this is the case in what follows[16]. Also, as discussed above, entrepreneurial effort does not play a central role here, so we assume that the cost of supplying this effort is zero i.e. $\psi = 0$, in which case $e = 1$. So, then output is $F(k, 1) \equiv f(k)$.

We begin at Stage 3. From (2.3), an entrepreneur located in $i = 1, 2$ buys capital up to the point where $f'(k_i) = (1 + m_i)r = z_i r$, where m_i is defined in (2.3) above. Solving this condition for k_i, we obtain the demand for capital by a firm located in country i i.e. $k_i = k(z_i r)$. Finally, the maximum profit of an entrepreneur, given a tax system (τ, z) is

$$(1 - \tau) \max_{k}\{(f(k) - zrk\} = (1 - \tau)\pi(z, r). \tag{2.4}$$

Note by the envelope theorem, $\pi_z = -rk,\ \ \pi_r = -zk$.

Moving to stage 2, some entrepreneur initially resident (say) in country 1 with cost $\hat{c}$ is indifferent between moving and not if

$$\hat{c} = (1 - \tau_2)\pi\left(z_2, r\right) - (1 - \tau_1)\pi\left(z_1, r\right). \tag{2.5}$$

This uniquely defines $\hat{c}$ as a function of the tax parameters in each country. Note also that total differentiation of (2.5) gives:

$$\frac{\partial \hat{c}}{\partial \tau_1} = \pi\left(z_1, r\right) > 0,\ \frac{\partial \hat{c}}{\partial z_1} = \left(1 - \tau_1\right) r k_1 > 0. \tag{2.6}$$

This is intuitive: as the statutory tax rate or EMTR increases, country 1 becomes a less attractive location.

Now consider the government's choice of tax at stage 1. The government can tax only the $1 - H(\hat{c})$ entrepreneurs resident in the country, and can tax both their rents and their use of

[16] This is a reasonable assumption, as we are mainly concerned with the "local" properties of the reaction functions in a neighbourhood of symmetric Nash equilibrium.

capital. So, the government budget constraint for country 1 is of the form

$$g_1 = (1 - H(\hat{c}))\left[\tau_1 \pi\left(z_1, r\right) + (z_1 - 1) r k_1\right]. \tag{2.7}$$

The objective of government is to maximize the sum of utilities of agents resident in the country. To calculate the latter, note that the consumption of the private good by each agent is equal to their after-tax income, which in the case of any capitalist is κr , and in the case of the entrepreneur in country 1 is $(1 - \tau_1)\, \pi\left(z_1, r\right)$. So, the objective of government is

$$W_1 = r\kappa + v\left(g_1\right) + (1 - H(\hat{c}))\left[(1 - \tau_1)\, \pi\left(z_1, r\right) + v\left(g_1\right)\right]. \tag{2.8}$$

Government 1 chooses taxes τ_1, z_1 to maximize W_1 subject to (2.7), and equilibrium condition (2.5) determining $\hat{c}$, but taking τ_2, z_2 fixed. Country 2 behaves in a similar way. Recall that the statutory rates are constrained to be between zero and one i.e. $0 \leq \tau_i \leq 1$ and also that a_i is non-negative, which implies that $z_i \leq 1/(1 - \tau_i)$. We can now show that (given a technical assumption) governments will *never* use the tax on capital, as long as their profit tax is less than fully used i.e. $\tau_i < 1$. The required assumption is the following:

A1. *W_1 is strictly quasi-concave in τ_1, z_1, treating $\hat{c}$ as endogenous via (2.5), but taking τ_2, z_2 as fixed.*

This assumption rules out local maxima of W_1 that are not global for fixed (τ_2, z_2). It does not rule out multiple tax equilibria. Our result[17] is:

Proposition 1 *(Optimality of cash-flow taxes). Assume A1 holds. Then, if the government in country i chooses $\tau_i < 1$, it will choose $z_i = 1$, whatever the tax policy of the other government.*

The intuition is that a capital tax (a less than full allowance) causes a *double distortion*, in that it causes outward migration of firms, *and* inefficient use of capital by the remaining firms, whereas a tax on rents distorts only location decisions. So, when the tax on rents is not being fully used ($\tau_i < 1$), it is never desirable to use the double-distorting capital tax (hence $z = 1$ or $m = 0$).

Proposition 1 indicates that, in the terminology of Section 2.1.3, the two countries react only in statutory taxes whenever $\tau_1, \tau_2 < 1$. We can now study the reaction functions in statutory tax rates implicitly defined by the first-order conditions for τ_1, τ_2 under some additional assumptions. Assume that the relocation cost is uniform on $[0, 1]$ i.e. $H(c) = c$. Further assume that v is linear i.e. $v(g) = \gamma g$: this assumption may seem strong, but it encompasses a revenue-maximising, or Leviathan, government, as a limit special case (when $\gamma \to \infty$).

[17] Proofs of this result, and Proposition 3 are in Appendix A.

Then it can be shown (see Appendix B) that the reaction function $\tau_1 = R(\tau_2)$, in implicit form ,satisfies the equation

$$-(1-\hat{c}) + (2-\hat{c})\gamma(1-\hat{c}) - (1-\tau_1)\hat{\pi} - \gamma(1-\hat{c})\tau_1\hat{\pi} - (2-\hat{c})\gamma\tau_1\hat{\pi} = 0, \tag{2.9}$$

where $\hat{c} = (\tau_1 - \tau_2)\hat{\pi}$.At the symmetric Nash equilibrium in taxes, $\tau_1 = \tau_2 = \tau$, $\hat{c} = 1$. So, setting $\tau_1 = \tau_2 = \tau$, $\hat{c} = 1$ in (2.9), and solving, we obtain

$$\tau^* = \frac{2\gamma - 1 - \hat{\pi}}{\hat{\pi}(3\gamma - 1)}. \tag{2.10}$$

This is the Nash equilibrium tax only if $0 \leq \tau^* \leq 1$, which requires $\frac{1}{2-3\hat{\pi}} \geq \gamma \geq \frac{1+\hat{\pi}}{2}$. Next, we can show[18]:

Proposition 2. *Assume that the Nash equilibrium is interior i.e.* $0 < \tau^* < 1$. *Then, in the neighborhood of Nash equilibrium* τ^**, the reaction function has slope between zero and 1 i.e.* $0 < R' < 1$ *and is strictly concave i.e.* $R''(\tau^*) < 0$.

The intuition for this result is simplest in the special case of Leviathan governments. Suppose that country 1 is the high-tax country. Then, when country 2 cuts its statutory tax by $\Delta\tau_2$, from (2.6), this leads to an increase in $\hat{c}$ of approximately $\Delta\hat{c} = \pi(1,r)\Delta\tau_2$, recalling that $z_1 = 1$ by Proposition 1. Now, from (2.7), this increase in $\hat{c}$ implies a reduction in 1's tax revenue of

$$\Delta\hat{c} \times \tau_1 h(\hat{c})\pi(1,r) = \tau_1 h(\hat{c})(\pi(1,r))^2 \Delta\tau_2.$$

as $(1 - H(\hat{c}))\pi(1,r)$ is 1's tax base. As r is constant from country 1's point of view, it is clear that the loss of tax revenue is greater for country 1, the higher its initial tax. So, the higher τ_1, the stronger the incentive for country 1 to follow 2's cut and win back some of its tax base.

One further issue must be addressed before proceeding to the next variant of the model. That is that Proposition 1 generally does not hold in the data reported below. Certainly for equity-financed investment[19], z generally exceeds 1. There may be a number of reasons for this. One possible reason concerns the treatment of losses. Giving full relief for all expenditure when it is incurred (or some equivalent alternative) implies that governments may end up subsidising loss-making investment. Typically, they are reluctant to do this. One response may be to choose a lower value of a and hence a higher value of z. In this case, the government will tax capital as well as economic rent, by imposing a positive EMTR. Conditional on this, governments can still compete for firm location by choosing an appropriate statutory tax rate. However, for $a < 1$, the tax on economic rent is measured by the EATR, λ, rather than the statutory rate.

[18] The proof of this result, and the corresponding Proposition 4, is in the longer, working paper, version, Devereux, Lockwood and Redoano (2002).

[19] Although it may be close to 1 for debt-financed investment.

It is of course possible to impose an upper bound on a, and solve the model in terms of the EATR, λ. If we further made the assumption that the scale of the project, k were fixed, then $\hat{\pi}$ would not depend on the EMTR. In that case, the definition of post-tax profit could be written as $(1-\lambda)\hat{\pi}$ instead of $(1-\tau)\hat{\pi}$ as implied by (2.4) and Proposition 1. The critical value of $\hat{c}$ in (**??**) would be replaced by $\hat{c} = (1-\lambda_2)\,\hat{\pi} - (1-\lambda_1)\,\hat{\pi}$.The definitions of the budget constraint and welfare would also have τ replaced by λ. The remaining analysis would then continue unchanged except that governments would compete over λ rather than τ. Of course, if the assumption of a fixed scale is relaxed, then $\pi(z,r)$ depends on z ,and the precise form of competition would differ.

In the empirical work below, we explore the two possibilities of competition over the statutory rate and the effective average tax rate.

2.3. Corporate Tax Competition when Firms are Immobile

From Table 1, our assumptions are now that (i) entrepreneurs are no longer mobile: (ii) the two countries are "large" relative to the capital market. Also, we assume for simplicity that $F(k,e) = f(k) + e$. We begin at the third stage. using the definition of z_i, we see that the net profit of any entrepreneur located in country i who hires k units of capital is:

$$(1-\tau_i)\left\{f(k) + e - z_i r k\right\} - \psi e. \tag{2.11}$$

The optimal level of capital for this entrepreneur maximizes (2.11) and so solves $f'(k_i) = q_i = z_i r$. Inverting this gives the demand for capital, $k_i = k(q_i)$. Moreover, the optimal effort of the entrepreneur maximises (2.11) and so satisfies

$$e(\tau_i) = \begin{cases} 0 & if\ \tau_i > 1-\psi \\ 1 & if\ \tau_i \leq 1-\psi \end{cases} \tag{2.12}$$

Also, define the profit function[20]

$$\begin{aligned} \pi(q_i,\tau_i) &= \max_{k,e}\{(1-\tau_i)(F(k,e) - q_i k) - \psi(e)\} \\ &= \max_{k}\{(1-\tau_i)(f(k) - q_i k)\} + \max\{1-\tau_i-\psi, 0\}. \end{aligned} \tag{2.13}$$

Note by the envelope theorem, from (2.13), $\pi_q = -(1-\tau_i)k$.

At stage 2, r is determined via world equilibrium in the capital market. The equilibrium condition is that the sum of demands equals world supply, 2κ:

$$2\kappa = k(q_1) + k(q_2) = k(z_1 r) + k(z_2 r). \tag{2.14}$$

[20]Note that this profit function is defined net of the statutory tax τ_i, unlike the profit function of the previous section. This difference is simply for algebraic convenience.

Now consider the government's choice of tax at stage 1. The government budget constraint for country 1 is

$$g_1 = \tau_1 \left[F(k_1, e_1) - z_1 r k_1\right] + (z_1 - 1)\, r k_1 \tag{2.15}$$

where $k_1 = k(q_1)$. The interpretation is as in the previous model: the government can tax both pure profit (after accounting for the tax on capital).which is the first term in (2.15), and also can tax capital.

As before, the objective of government in country 1 is to maximize the sum of utilities of agents resident in the country. So, the maximand of government in country 1 is:

$$W_1 = \kappa r + v(g_1) + \pi(q_1, \tau_1) + v(g_1). \tag{2.16}$$

The government of country 1 chooses (z_1, τ_1) to maximize W_1 subject to budget constraint (2.15) and equilibrium condition (2.14) determining r, but taking (z_2, τ_2) fixed. Country 2 behaves in a similar way. It is convenient to assume in fact that governments $1, 2$ choose the cost of capital q_1, q_2 directly, rather than the tax variables.

Consider first country 1's choice of τ_1. W_1 is not differentiable in τ_i, as effort is not differentiable in τ_i. However, as long as the public good is desirable when taxes are lump-sum (i.e. $2v'(0) > 1$) the possibilities for the government are clear: either tax at a level $\tau_i = 1 - \psi$, which will induce the entrepreneurs to put in maximum effort, or tax at $\tau_i = 1$, which discourages effort. In a special case, as closed-form solution to this problem can be found:

Proposition 3. *Assume that utility is linear in income i.e.* $v(g) = \gamma g$. *Then,* $\tau_i = 1 - \psi$ *iff*

$$\frac{2\gamma(1-\psi)}{(2\gamma - 1)\psi} \geq f(k_i) - z_i r k_i = \phi_i \tag{2.17}$$

Otherwise, $\tau_i = 1$.

For reasons discussed above, it is desirable to have countries choosing statutory tax rates of less than 100%, so we will assume that utility from the public good is linear and that condition (2.17) holds in what follows, so $\tau_i = 1 - \psi$. Note from Proposition 3 that the choice of τ_1 is independent of τ_2 and vice versa, establishing the claim that in this model, countries do not compete in statutory rates.

Now consider country 1's choice of q_1. Assuming an interior solution for q_1, the first-order condition for q_1 implicitly defines a reaction function[21] $z_1 = R(z_2)$ which describes how country 1's EMTR reacts to country 2's. To investigate further, we will assume from now on that the production function is quadratic ($f(k) = k - \frac{k^2}{2}$). As utility is already assumed linear in the

[21] Note that without terms of trade effects i.e. with countries taking r as fixed, the first-order condition for

public good, we refer to this as the *linear-quadratic* case. In can then be shown (Appendix B) that the reaction function takes the following implicit form:

$$(2\gamma-1)\,\psi(1-z_1r)-2\gamma(z_1-1)r+\frac{1}{z_2}\left\{2\gamma(1-z_1r)-\kappa\right\}=0. \tag{2.18}$$

where $r=\frac{2(1-\kappa)}{z_1+z_2}$ is the equilibrium interest rate. At a symmetric Nash equilibrium, where $z_1=z_2=z^*$, $r=(1-\kappa)/z$, so (2.18) gives[22]:

$$z^*=\frac{2\gamma-\kappa}{2\gamma(1-\kappa)-(2\gamma-1)\psi\kappa}. \tag{2.19}$$

Now, recalling that $z_i\leq 1/(1-\tau_i)$, and by Proposition 3, $\tau_i=1-\psi$, the Nash equilibrium tax must satisfy $\frac{1}{\psi}\geq z^*$: if z^* as defined in (2.19) does so strictly, we will say that it is *interior.* Using (2.19), the condition for $\frac{1}{\psi}\geq z^*$ reduces to $\kappa\leq\gamma(1-\psi)/(\gamma+\gamma\psi-\psi)\equiv\kappa_0$ i.e. the world supply of capital not be too large.

We now turn to the properties of the reaction function $z_1=R(z_2)$ implicitly defined by (2.18). In the neighborhood of the Nash equilibrium, R has the following properties:

Proposition 4. *Assume that the Nash equilibrium is interior and that $\kappa\leq\frac{2\gamma}{4\gamma-1}$. In the linear-quadratic case, in the neighborhood of Nash equilibrium τ^*, the reaction function has slope between zero and 1 i.e. $0<R'<1$ and moreover, is strictly concave i.e. $R''(\tau^*)<0$.*

Compared to Proposition 2, this requires an additional condition, on κ. However, this condition is not that strong. The bound on κ is at least 0.5, and can be compared to the condition for an interior solution, which is $\kappa\leq\kappa_0$. In fact, it is possible to show that $\kappa_0<\frac{2\gamma}{4\gamma-1}$ whenever $\psi>1/3$. As $\tau=1-\psi$, this implies that the bound on the capital stock always holds at an interior Nash equilibrium whenever $\tau<0.7$. The statutory corporate tax rates in our sample are all below this level.

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q_1 reduces to a modified Samuelson rule for public good provision:

$$2v'(g_1)=\frac{1}{1-(z_1-1)\varepsilon_1/(1-\tau)z_1}$$

where $\varepsilon_1=-q_1k'/k_1$ is the elasticity of demand for capital, which depends only on r and z_1. This is a standard formula (Zodrow and Mieszkowski(1986)). Note also that given r fixed, this equation determines z_1 *independently* of z_2, which proves the claim of Section 2.1.3 above that there are no tax reaction functions in the ZMW model.

[22] Combining (2.18) with the formula for r, and rearranging, we get:

$$(2\gamma-1)\psi[z_1+z_2-2(1-\kappa)z_1]z_2-4\gamma(1-\kappa)(z_1-1)z_2+2\gamma[z_1+z_2-2(1-\kappa)z_1]-(z_1+z_2)\kappa=0.$$

Setting $z_1=z_2=z^*$ in the above equation gives us:

$$(2\gamma-1)\psi 2\kappa z^*-4\gamma(1-\kappa)(z^*-1)+4\gamma\kappa-2\kappa=0$$

and solving this second equation for z^* gives (2.19).

2.4. Testable Implications of the Properties of the Reaction Functions

Propositions 2 and 4 state that, given some conditions, reaction functions are upward sloping and concave in the neighborhood of equilibrium. We would argue that these conditions are reasonable. First, the assumption of a quadratic production function in Proposition 4 can be regarded as a second-order approximation to a general concave production function. Second, the assumption of a uniform distribution of relocation costs in Proposition 2 is the borderline case between concave and convex distributions, and is thus a "neutral" assumption i.e. not biased in any direction. Finally, the assumption of utility linear in the public good (made for tractability) tends to *understate* the concavity of the reaction function. Consider the case in Proposition 2, for example. Following a given tax reduction by country 2, the loss of public good is higher for country 1, the higher its initial tax, and this partly explains the concavity of the reaction function. Now, note that if v is strictly concave, country 1 has a *second* reason to do this: a reduction in public goods supply is more costly when g_1 is already low. But, in any case, our main argument is rather that reaction functions are unlikely to be linear, and so our empirical work should allow for some non-linearities.

3. Empirical Specification of the Tax Reaction Functions

The theoretical analysis in Section 2 generated symmetric reaction functions of the form $T_i = R(T_j)$, where, in what follows, T_i will denote the tax rate (whether statutory, EATR, or EMTR) in country i. The theoretical model assumed two symmetric countries. Allowing for n countries that may be different, and introducing time subscripts, the reaction functions can be written more generally as

$$T_{i,t} = R_i\left(\mathbf{T}_{-i,t},\ \mathbf{X}_{it}\right) \qquad\qquad i = 1,...n \tag{3.1}$$

where $\mathbf{T}_{-i,s} = (T_{1s}, T_{2s}, ..T_{i-1s}, , T_{i+1s}, ...T_{ns})$ denotes the vector of tax rates of all other countries at time s, and $\mathbf{X}_{it}$ is a vector of other control variables that may affect the setting of the tax in country i. However, (3.1) cannot be estimated as it stands.

The first issue is that of degrees of freedom. In principle, each country could respond differently to the tax rates in every other country. But then, even if (3.1) were linear in $\mathbf{T}_{-i,t}$, and the coefficients on the elements of $\mathbf{T}_{-i,t}$ were constant over time, then with 21 countries in our data set, this would imply estimating 21 x 20 = 420 different parameters, which is clearly not feasible. It is therefore necessary to make some assumptions about these parameters. In practice, we follow the existing literature by using a weighted average i.e. we replace the vector

$\mathbf{T}_{-i,t}$ in (3.1) by:

$$A_{i,t} = \sum_{j \neq i} \omega_{ij} T_{jt}$$

That is, we suppose that every country responds in the same way to the weighted average tax rate of the other countries in the sample.

In our case, the appropriate choice of weights $\{\omega_{ij}\}$ is not obvious. In principle, we would like the weights to be large when tax competition between countries i and j is likely to be strong. In the case of local property taxes, the obvious choice (and one that works well in practice, see e.g. Brueckner (2000)) is to use geographical weights, where ω_{ij} is inversely related to the distance between jurisdictions i and j. A local government is likely to respond more readily to changes in the tax rates of neighboring governments than it would to rates in a different part of the country. However, in our case, the degree of tax competition between two countries may depend not only (or at all) on geographic proximity of countries, but also their relative size and the degree to which they are open to international investment flows. We investigate each of these possibilities in our empirical work.

A second issue is that in practice, our tax rates are highly serially correlated, perhaps because abrupt changes in the tax system are likely to be costly to governments, either because such changes impose costs of adjustment on the private sector, or because such changes may be blocked at the political level by interest groups who stand to lose from the change. We include a lagged dependent variable in (3.1) to allow for this.

A third issue is one of timing. One problem with estimation of equations (3.1), viewed as a system, is that it imposes the restriction that taxes are continuously (i.e. in every period) at their Nash equilibrium values. This seems implausible: even within game theory, it is increasingly accepted that Nash equilibrium is best interpreted as the outcome of some adjustment process (Fudenberg and Tirole, 1991). One very simple adjustment process that generates testable reaction functions is to suppose that the government in each country sets the tax as a myopic best response to the taxes in the previous period in other countries[23]. This would generate reaction functions as in (3.1), except that $T_{-i,t}$ is replaced by $T_{-i,t-1}$. We call this specification of the reactions functions the *lagged* specification, and (3.1) the *contemporaneous* specification. The disadvantage of the lagged specification is that it is not directly consistent with the theory: in particular, governments are assumed myopic in the sense that they do not anticipate any change in other countries' tax rates either due to changes in underlying economic conditions, or

[23] This process will only converge to the Nash equilibrium under certain conditions, however. For example, if $n = 2$, this system is locally stable around a given Nash equilibrium if the slope of $R(T_1)$ is greater than the slope of $R(T_2)$ in (T_1, T_2) space. In this case, starting in the neighborhood of Nash equilibrium, taxes will (in the absence of exogenous shocks) eventually converge to their Nash values.

as a result of the other governments' myopic reactions to current taxes. As both specifications have their (dis)advantages, we estimate both. This is in contrast to the literature, where (as far as we are aware) all empirical work on tax competition estimates one or the other on a given data-set, with most studies working with the contemporaneous specification[24] (Brueckner, 2000).

So, the preceding discussion suggests two possible specifications, which can be written as

$$T_{i,t} = R_i\left(T_{i,t-1},\ A_{is},\ \mathbf{X}_{it}\right) \qquad\qquad i = 1, ...n \tag{3.2}$$

where $s = t$ (resp. $s = t - 1$) gives the contemporaneous (resp. lagged) specification. These two approaches raise different econometric issues, which we discuss below.

The final issue is the choice of functional form of R_i. We assume R_i is linear in $(T_{i,t-1}, \mathbf{X}_{it})$. However, as discussed above, we also wish to examine the possibility of a concave relationship between $T_{i,t}$ and A_{is}. We allow for this by permitting the reaction of a country with a tax rate above the average (appropriately defined) to react more to tax changes of the other countries than do countries who have a tax rate below the average[25]. Specifically, we suppose that R_i is piece-wise linear in A_{is}, modifying (3.2) to

$$T_{it} = \alpha + \beta T_{it-1} + \gamma_1 A_{is} + \gamma_2 D_{is} + \gamma_3 D_{is} A_{is} + \boldsymbol{\eta}' \mathbf{X}_{it} + \eta_i + \eta_t \tag{3.3}$$

where

$$D_{is} = \begin{cases} 1 & \text{if } T_{is} > A_{is} \\ 0 & \text{if } T_{is} < A_{is} \end{cases}$$

and where η_i is a country fixed effect, and η_t is a period fixed effect[26].

D_{is} is a dummy indicating whether country i's tax rate is above or below the weighted average in period s. This dummy appears on its own, and interacted with A_{is}. Thus, we allow for two possibilities: simply being above the average may change the intercept of the reaction function; and being above the average may change the way T_{it} responds to changes in the weighted average of the other taxes. It is clear from the discussion of Section 2.4 that concavity of the reaction function requires $\gamma_2 < 0$ and $\gamma_3 > 0$. So, our piece-wise linear specification captures in a fairly crude way the concavity of reaction functions predicted by the theory.

[24] There are, however, a few papers estimate the lagged specification eg. Hayashi and Boadway (2000).

[25] We choose the (weighted) average of the other taxes as a switchpoint for the following reason. The theory developed above shows that the reaction function is concave *in the neighborhood of the symmetric Nash tax equilibrium.* It follows from this that country 1 will react more (less) to country 2 when 1's initial tax is above (below) 2's tax i.e. the switchpoint is when the two taxes are equal. The n-country generalisation of this, of course, is when country 1's tax is equal to the average of all the other countries' taxes.

[26] Note also that we do not allow the coefficients in (3.3) to vary by country, again to preserve degrees of freedom.

4. Data

The empirical approach in this paper is to estimate (3.3). To do this, we use data on the corporate tax regimes of 21 OECD countries over the period 1982 to 1999. As is clear from the previous section, there are several different possible measures of effective tax rates which can be analysed. In Section 4.1 we describe the measures which we use in this paper. We also include a number of control variables in the analysis; these are described in Section 4.2.

4.1. Effective Tax Rates

There are two broad approaches to the measurement of effective tax rates on capital income. One, proposed for example by Mendoza et al (1994), is based on the ratio of tax payments to a measure of the operating surplus of the economy. This approach is not ideal for analyzing competition between jurisdictions over taxes on corporate income, for several reasons. First, at best it is a measure only of the effective average tax rate, and so cannot be used to distinguish the two models described in the previous section. Second, it does not necessarily reflect the impact of taxes on the incentive to invest in a particular location, because tax revenues depend on the history of past investment and profit and losses of a firm, and also the aggregation of firms in different tax positions. Third, this measure can vary considerably according to underlying economic conditions, even when tax regimes do not change; the variation is therefore due to factors outside the immediate control of the government.

The effective tax rate measures used in this paper are therefore based on an analysis of the legislation underlying different tax regimes. Specifically, we use the measures proposed by Devereux and Griffith (2002). Following the standard approach, they consider the taxation of a hypothetical unit perturbation to the capital stock. The cost of the increased capital stock is offset by tax allowances, defined by the legislation. The additional revenue is taxed. Using this approach, it is possible to derive measures of the EMTR and the EATR, corresponding to those set out in Section 2. A brief summary of the approach is provided in Appendix B. In this paper, we consider four types of investment, corresponding to two assets - plant and machinery and industrial buildings - and two sources of finance - equity and debt. Each of these investments has a corresponding EATR and EMTR.

In estimating reaction functions, we face a choice of which hypothetical investments to use. We have experimented with three approaches. First, we considered each investment separately. This revealed some differences in results, primarily depending on whether the investment is financed by equity or debt. Our main finding was that the results based on equity financed-investments were more in line with the theoretical predictions, but that the results were not sensitive to the choice of asset. For reasons of space, we report in Tables 3 and 4 only results based on an investment in buildings financed by equity. Second, we construct a weighted average across the four hypothetical investments. This is also shown below in Table 5. Third, we have also experimented with stacking two of the investments,[27] thereby generating twice as many observations. However, this approach does not generate different qualitative results, and so, again for reasons of space, is not shown here.[28]

We construct the EMTR and the EATR from the statutory tax rate and the allowance rules, between 1983 and 1999 for 21 high income OECD countries. Theses data were collected from a number of sources. Chennells and Griffith (1997) provide information for 10 countries up to 1997. These data have been extended to other countries and later years using annual summaries from accounting firms, notably Price Waterhouse tax guides (Price Waterhouse, 1983 to 1999). We apply the same economic parameters (the interest rate, inflation rate and depreciation rates) to all countries in all years.[29] Thus the measures are not intended to provide the best possible estimate of the EMTR or the EATR in each year; rather they are intended to focus on differences between countries and over time only in the tax regimes themselves.

The tax rates are briefly summarised in Figure 1, which presents for each year the three measures of taxation, averaged across countries, weighted by GDP. The lines represent the statutory tax rate (including local taxes on corporate profit), and the EATR and EMTR for the weighted average of the four types of investment. A thorough description of the development of these taxes is provided in Devereux, Griffith and Klemm (2002).

4.2. Other variables

Clearly other factors may also influence a government's choice of corporation taxes. In the empirical formulation below, we therefore depart from the assumption of symmetric countries used for simplicity in the theoretical mode, by including a number of control variables in our regression. .

It has frequently been argued that corporation tax is a necessary "backstop" for income tax: that is, in the absence of corporation tax, individuals could potentially escape tax on their

[27] To maximise variation in the data, we choose dissimilar investments, for example, investment in buildings financed by equity, and investment in machinery financed by debt

[28] Further results are presented in the working paper version of this paper: see Devereux, Lockwood and Redoano (2002).

[29] Inflation is set to 3.5% and the real interest rate to 10%. Economic deprecaition rates are taken from OECD (1991), and assumed to be 12.25% for machinery and 3.61% for industrial buildings.

earnings by incorporating themselves. One important control variable is therefore the highest domestic income tax rate, TOPINC_{it}. These rates are collected from comparable sources to those for corporation tax: primarily annual guides from accounting firms, and specifically those from Price Waterhouse. In addition, we introduce other control variables which describe economic and demographic characteristics which may plausibly affect the setting of taxes, as listed below:

Table 1: Control Variables

SIZE_{it}	relative size of each economy, measured as $\frac{GDP_{it}}{GDP_{jt}}$- where j=USA;
PCON_{it}	total public consumption, as a proportion of GDP_{it}
OPEN_{it-1}	sum of inward and outward foreign direct investment, as a proportion of GDP_{it},lagged one year
PYOU_{it}	proportion of population below 14 years old
POLD_{it}	proportion of population 65 year old
PURB_{it}	proportion of population living in urban areas
PDENS_{it}	population density
TOPINC_{it}	highest marginal income tax rate

Sources: GDP and Public Consumption : OECD National Accounts, various years, Tax Revenue: OECD Revenue Statistics, various years, GDP, Exchange Rates: Datastream, Population data: World bank - HNP Statistics, FDI: OECD International Direct Investment Statistics Yearbook.

We have also experimented with various political controls, such as election-year dummies. However, these proved to be insignificant in the estimation and are therefore not reported.

5. Econometric Issues

From the discussion in Section 3, our system of equations to be estimated is

$$T_{it} = \alpha + \beta T_{it-1} + \gamma_1 A_{is} + \gamma_2 D_{is} + \gamma_3 D_{is} A_{is} + \boldsymbol{\eta}' \mathbf{X}_{it} + \eta_i + \eta_t + \varepsilon_{it},\ i = 1, ..n \tag{5.1}$$

First, consider the contemporaneous version of (5.1), in which $s = t$. In this case, since the model predicts that all tax rates are jointly determined, it clearly indicates endogeneity of A_{it} and hence D_{it}. The empirical literature has typically dealt with this endogeneity by estimating the equation using maximum likelihood (see Brueckner, 2001 for a survey of empirical techniques). However, this is complicated in our case by the need to allow for a non-linear response of T_{it} to A_{it}. We therefore follow a different approach, using instrumental variables. As a first stage, we first regress T_{it} on $(T_{it-1}, \mathbf{X}_{it})$ - that is the control variables for country i. We estimate this as a panel, and derive predicted values of T_{it}. Assuming the weights to be exogenous, we then generate the weighted average of the predicted values. We use this weighted average to generate D_{it}. In the lagged case, in which $s = t-1$, we treat the weighted average of the lagged tax rates of other countries as being exogenous.

Unlike the maximum likelihood approach, the IV approach is robust to spatial correlation in the error term, ε_{it}. Nevertheless, we test for such spatial correlation using the Burridge (1980) test. We also test for first order auto-correlation in the error term, using a standard test (see Baltagi, 1996). The test for autocorrelation is straightforward, since we test for correlation between ε_{it} and ε_{it-1}. In investigating correlation across countries, however, there are 21 observations in each period: it is not clear what ordering they should have for the purpose of the test. Following Burridge, we combine the residuals from the other countries using the weighting matrix (for more details, see also Anselin et al, 1996). Each of the test statistics is distributed as χ^2 with one degree of freedom.

In principle, we would want to include time effects, to capture shocks in each period which are common to all countries. However, this is not always possible, since such effects are already largely included in the weighted average and the lagged dependent variable. To see this, consider the lagged model, and note that we can write $A_{i,t-1}$ (in the unweighted case, for example) as

$$A_{i,t-1} = \frac{\sum_{j=1}^{n} T_{j,t-1}}{n-1} - \frac{T_{i,t-1}}{n-1}$$

The first term on the right-hand side of this is just n/(n-1) times the average tax rate across all countries, which varies only over time. So, if time dummies are also included in the regression, it is impossible to identify the effect of this first term separately. So, the identification of the coefficient on $A_{i,t-1}$ in the regressions would therefore be from the second right-hand side term. But this is simply the negative of the (scaled) lagged dependent variable. The conclusion is that including time dummies, as well as a lagged dependent variable in the regression means that the coefficient on $A_{i,t-1}$ cannot be identified. As this coefficient is our main focus of interest, this is unacceptable, so we do not include year dummies in the lagged specification: we use a country specific time trend instead. This problem is clearly less severe for the contemporaneous model i.e. the variables $A_{i,t}, T_{i,t-1}$ and are no longer perfectly correlated, but there may still be considerable multicollinearity as $T_{i,t}, .T_{i,t-1}$ are strongly correlated: again, in this specification, we use a country specific time trend.

6. Empirical Results

We present the main results in four tables. Each table contains 8 columns. The first four columns present results for the contemporaneous model ($s = t$); the second four contain results for the lagged model ($s = t - 1$). Each of the four columns represents a different weighting matrix in computing the weighted average tax rate. Specifically, we present results for the following weights: (a) unweighted; (b) weighted by distance - that is, the reciprocal of the distance between the capital cities of countries i and j; (c) weighted by GDP; (d) weighted by average over three years of the total of inward and outward flows of foreign direct investment lagged three years. In all cases, we present robust standard errors and the two LM tests for serial correlation and spatial correlation in the error terms.

Tables 2 and 3 present results based on the first model of Section 2. In that model, reaction functions were based on the statutory tax rate or the EATR. In Table 2, we present results using the statutory tax rate. In Table 3, we present the alternative using the EATR as described in Section 4 and Appendix B. Table 4 presents estimates based on the second model in Section 2; this model generated reaction functions based on the EMTR. Finally, Table 5 presents the case for the contemporaneous model where the weighted average EATR and EMTR are used. In all cases, there are 357 observations (21 countries and 17 years). We include country fixed effects, and a country specific time trend.

Consider first Table 2. In all cases, the lagged dependent variable is highly significant, with an estimated coefficient of around 0.5. Of the control variables, two are highly significant. One is the top income tax rate, which has a positive effect, indicating that countries with higher income tax rates are likely to have higher corporation tax rates; this is consistent with the explanation given above, and is present in all the tables. The other is size: other things being equal, large countries have higher statutory tax rates; this is also true in Table 3 for the EATR, but only partially so for the EMTR. Again this is consistent with theory: the more impact a country's policies have on the world rate of return to capital, the higher it can set its corporate tax rate. Other control variables are significant in only some of the specifications in Table 2. The LM tests indicate that there is neither serial correlation, nor spatial correlation, in any of the specifications in the Table.

The effects of the (unweighted) average of other tax rates is consistent with the model presented in Section 2.2. For example, in column I, the overall impact of the average is significant and positive, suggesting that there is indeed a positively sloped reaction function in statutory tax rates. In addition, there is a large and significant effect in the case in which country i's tax rate exceeds the average. The dummy variable indicating this has a negative and significant effect, indicating that simply being above the average tends to reduce country i's tax rate. In addition, the average tax rate multiplied by the dummy has a positive and significant effect, indicating that, in addition, country i's response to movements in other countries' tax rates is greater if country i is above the average. These results support the prediction of concavity of the reaction function.

In column I, the long-run magnitude of these responses is as follows. If country i is below the unweighted average, then a one percentage point fall in the average will induce country i to reduce its rate by nearly 0.6 percentage points. But if country i is above the unweighted average, there are two additional effects. First, simply being above the average would induce country i to reduces its tax rate by nearly 0.3 percentage points. Second, a one percentage point fall in the average will induce country i to reduce its rate by 0.75 percentage points. These magnitudes are large. Suppose country i has a tax rate above the average, and suppose that the average falls by one percentage point. Overall, we would expect country i to reduce its tax rates by around 1.63 percentage points. The magnitudes of these effects are reasonably common to all the specifications, although the effects of the overall weighted average is a little lower under the other forms of weighting, and is not always significant. However, the effects are strong and consistent in the case in which country i's tax rate exceeds the average.

The results of the lagged model, presented in columns 5 to 8, are rather different. There is evidence of some asymmetric adjustment to the mean in three of the cases considered (not with GDP weights). However, in only one case is there a significant response to the weighted average. On balance, this comparison between the two possibilities on timing is therefore in favour of the contemporaneous model.

Table 3 presents results for the EATR for the single type of investment in buildings, financed by retained earnings. The results here are very similar to those for the statutory tax rate in Table 2, although more consistent across the different specifications. Country size and the top income tax rate are again always positive and highly significant. Of the other control variables, the proportion of elderly has a positive and significant effect in column I, and the proportion of young sometimes has a negative effect. Again, there is no evidence of serial or spatial correlation. The significance and magnitude of the results on the average tax rates of other countries are slightly larger than in Table 1. In column I, for example, if country i's tax rate exceeds the average and the average falls by one percentage point, then in the long run country i would reduce its tax rate by just over 2 percentage points. An even greater effect is found under some of the other specifications. Once again, the lagged model does not generate a significant effect of the overall average, although there are strong asymmetric effects.

Table 4 presents the results for the second model of Section 2. That is, the tax rate used in these regressions is the EMTR, again for investment in buildings financed by retained earnings. Of the control variables, only the top income tax rate is consistently significant across all specifications, although country size is also significant in the contemporaneous model. This is perhaps not surprising; the EMTR measures the impact of corporation tax for a marginal investment. It does not necessarily reflect the tax revenue which may be generated.

In the contemporaneous model, the impact of the weighted average of other countries' tax rates follows a similar pattern to the two previous cases. In this model, the average tax rate terms are generally significant and have the expected sign. However, for the FDI-weighted model, there is only a significant effect for countries above the mean. The magnitudes of these coefficients are higher than in the case of the EATR although this masks differences in the means of the tax variables. Taking the unweighted column, for example, the long-run response of countries below the average to a one percentage change in the average would be to reduce their EMTR by 0.67 percentage points. In addition to this, countries above the average would reduce their EMTR in the long run by 0.86 percentage points, and would further respond to a one percentage point reduction in the average by cutting their EMTR by over 1.5 percentage points. The size of these effects is rather large, and perhaps implausible.

By contrast, three of the lagged versions of the model imply that there is no reaction to other countries' EMTRs. The only significant effects are asymmetric effects in the distance-weighted model. Overall, then, this Table suggests that evidence for competition in the EMTR is rather less robust than for competition in the statutory rate and the EATR.

Finally, in Table 5, we present results for the case in which the effective tax rates for the four different forms of hypothetical investment are combined into a weighted average. This table shows only the contemporaneous case; the first four columns are based on the EATR, and the last four columns are for the EMTR. These results are mixed. For the EATR, the only evidence of symmetric competition is in the distance weighted case. However, there is evidence of asymmetric competition using all four of the weights. There is rather more evidence of symmetric competition over the EMTR. This applies for using each of the three weights; and in each case there is little evidence of asymmetric competition. However, the reverse is true in the unweighted case, where there is evidence of evidence of asymmetric, but not symmetric competition. The difference in these results compared with those in the previous two tables seems to be largely as a result of including debt finance. The impact of interest deductibility can have counter-intuitive effects on the measures of effective tax rates, especially on the EMTR. For an example, an increase in the statutory rate can reduce the EMTR, since a higher proportion of interest charges can be reclaimed against tax. This implies that it is hard to envisage governments attempting to compete over the EATR and EMTR for both debt and equity finance, since changing the parameters of the tax regime can affect these measures in different ways. The combined results of Tables 3 to 5 suggest that governments focus more on the more intuitive and straightforward case of equity finance.

7. Conclusions

This paper presents an empirical analysis of competition in corporation taxes between 21 large industrialised countries, over the period 1982 to 1999. We consider two models of the competitive process, based on alternative assumptions about the mobility of capital and firms. These two models generate different predictions about the form of the relevant tax rate. The first model indicates that it is the statutory tax rate, or effective average tax rate (EATR), which affects the location decision of firms, and hence is competed over by governments. The second model indicates that the location of capital depends on the rate of allowances, or the effective marginal tax rate (EMTR). We test each of these models, by generating measures of each of these forms of tax rates, and then using them to estimate the determinants of countries' reaction functions.

Overall, the results suggest that governments compete over the EATR and the statutory tax rate. There is strong evidence also that this competition is asymmetric: that is, countries react more strongly to changes in other countries' tax rates when their own tax rate is above the average. This is consistent with the first model outlined in Section 2, in which firm location choices are discrete.

By contrast, the results for the second - and more standard - model in Section 2 are more mixed. In this model, flows of capital are determined by the EMTR, and this model too generates a prediction of asymmetric reactions. However, while there is some evidence that governments do react to the EMTRs of other countries, the nature of the response is less stable across the different specifications of the model. In some cases, there is no asymmetric response. In others, there is only a response if countries are above the mean. In general then, these results are supportive of the first model.

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A. Proofs of Propositions 1 and 3

Proof of Proposition 1. Assuming interior solutions for τ_i and z_i, the first-order conditions to this problem can be written as:

$$\frac{\partial W}{\partial \tau_1} = -\left(1 - H(\hat{c})\right)\pi_1 + (2 - H(\hat{c}))v'(g_1)\left(1 - H(\hat{c})\right)\pi_1 + \frac{\partial W}{\partial \hat{c}}\frac{\partial \hat{c}}{\partial \tau_1} = 0, \tag{A.1}$$

$$\frac{\partial W}{\partial z_1} = -\left(1 - H(\hat{c})\right)\left(1 - \tau_1\right)rk_1 + (2 - H(\hat{c}))v'(g_1)\left(1 - \hat{c}\right)\left[\left(1 - \tau_1\right)rk_1 + (z_1 - 1)r^2k_1'\right] + \frac{\partial W}{\partial \hat{c}}\frac{\partial \hat{c}}{\partial z_1} = 0 \tag{A.2}$$

where $\pi_1 = \pi\left(z_1, r\right)$, and the responses of $\hat{c}$ to τ_1, z_1 are given in (2.6). Assume w.l.o.g. that $0 < \tau_i < 1$, so (A.1) holds with equality (the corner case $\tau_i = 0$ is dealt with in a similar way). Then, from (A.2), using (2.6):

$$\frac{\partial W_1}{\partial z_1}|_{z_1=1} = \left\{-\left(1 - H(\hat{c})\right) + (2 - H(\hat{c}))v'\left(1 - H(\hat{c})\right) + \frac{\partial W_1}{\partial \hat{c}}\right\}\left(1 - \tau_1\right)rk_1. \tag{A.3}$$

Also, from (A.1), using (2.6):

$$\frac{\partial W_1}{\partial \tau_1} = \left\{-\left(1 - H(\hat{c})\right) + (2 - H(\hat{c}))v'\left(1 - H(\hat{c})\right) + \frac{\partial W_1}{\partial \hat{c}}\right\}\pi_1 = 0. \tag{A.4}$$

Clearly, (A.4) implies that $\frac{\partial W_1}{\partial z_1}|_{z_1=1} = 0$. So, by A1, the (globally) optimal choice of z_1 is 1, implying that the optimal choice of a_1 is also 1. □

Proof of Proposition 3. Substituting (2.15) into (2.16) and setting $\tau_i = 1 - \psi$ yields a payoff of

$$W_1(z_1, 1 - \psi : r) = r\kappa + \psi\phi_1 + 2v((1 - \psi)(\phi_1 + 1) + (z_1 - 1)rk_1)$$

but substituting (2.15) into (2.16) and setting $\tau_i = 1$ in (**??**) yields a payoff of

$$W_1(z_1, 1 : r) = r\kappa + 2v(\phi_1 + (z_1 - 1)rk_1).$$

Then, $W_1(z_1, 1 - \psi : r) \geq W_1(z_1, 1 : r)$ reduces to (2.17). □

B. Derivation of Formulae For Reaction Functions

B.1. Model 1

Note from (2.7), (2.8), $H(c) = c$, and the fact that $z_1 = 1$ that

$$\frac{\partial W_1}{\partial \hat{c}} = -\left(1 - \tau_1\right)\hat{\pi} - \gamma(1 - \hat{c})\tau_1\hat{\pi} - \left(2 - \hat{c}\right)\gamma\tau_1\hat{\pi}. \tag{B.1}$$

where $\hat{\pi} = \pi(1, r)$ is the profit before statutory tax when the capital tax is zero. So, substituting (B.1) in (A.1), we obtain the first-order condition which implicitly defines the reaction function $\tau_1 = R(\tau_2)$:

$$-(1-\hat{c}) + (2-\hat{c})\gamma(1-\hat{c}) - (1-\tau_1)\hat{\pi} - \gamma(1-\hat{c})\tau_1\hat{\pi} - (2-\hat{c})\gamma\tau_1\hat{\pi} = 0. \tag{B.2}$$

Noting that $\hat{c} = (\tau_1 - \tau_2)\hat{\pi}$ from (2.5) gives equation (2.9). $\square$

B.2. Model 2

Note that for τ fixed at $1-\psi$, the first-order condition for choice of q_1 is:

$$\frac{\partial W_1}{\partial q_1} = \big(2v' - 1\big)\psi k_1 + 2v'(q_1 - r)k_1' - \frac{\partial r}{\partial q_1}\big\{2v'k_1 - \kappa\big\} = 0 \tag{B.3}$$

Moreover, given the quadratic production function, demand for capital in country i is $k_1 = 1 - z_i r$ and consequently, from (2.14), the equilibrium interest rate is:

$$r = \frac{2(1-\kappa)}{z_1 + z_2}. \tag{B.4}$$

Next, to evaluate the terms of trade effect $\partial r/\partial q_1$ in (B.3), recall that $rz_1 = q_1$, and also that $\partial r/\partial z_1 = -r/(z_1 + z_2)$ from (B.4). So,

$$\frac{\partial q_1}{\partial z_1} = r + z_1\frac{\partial r}{\partial z_1} = \frac{z_2 r}{z_1 + z_2}$$

and consequently,we have:

$$\frac{\partial r}{\partial q_1} = \frac{\partial r}{\partial z_1}\frac{\partial z_1}{\partial q_1} = -\frac{1}{z_2} \tag{B.5}$$

So, substituting (B.5) in (B.3), recalling that in the linear-quadratic case, $v' = \gamma$, $k_1 = 1 - z_1 r$, $k_1' = -1$, we obtain:

$$(2\gamma - 1)\psi(1 - z_1 r) - 2\gamma(z_1 - 1)r + \frac{1}{z_2}\{2\gamma(1 - z_1 r) - \kappa\} = 0. \tag{B.6}$$

which gives (2.18) as required. $\square$

C. Description of Effective Tax Rates

We use the measures of effective tax rates set out by Devereux and Griffith (2002). Consider a hypothetical one period investment. At the beginning of the period, the firm increases its investment by purchasing an asset for unity. At the end of the period, it earns a return on this investment, denoted $p+\delta$ and reduces its investment in that period by 1-δ, where p is the (net) financial rate of return and δ is the economic rate of depreciation of the asset. The capital stock in all other periods is unaffected. Given these cash flows, it is possible to compute the tax liabilities and allowances which would be associated with such an investment. Comparing these flows pre- and post-tax permits an analysis of the impact of tax on the incentive to undertake the investment.

Within this framework, two distinct models can be distinguished, corresponding to the two models in Section 2. The second, comparable to King and Fullerton (1984), analyses the impact of taxation on the cost of capital - i.e. minimum pre-tax rate of return required to give a project zero net present value. Suppose in the absence of personal taxes that the discount rate of the marginal shareholder is r. Then, in the absences of taxes, the present value of the income generated at the end of the period is $V = (1+p)/(1+r)$. Since the cost of the investment is $C = 1$, then the cost of capital is $\tilde{p} = r$.

Denote the present value of allowances associated with the additional investment expenditure as A. In present value terms, the firm collects this at the beginning of the period so that the cost of the asset becomes $C = 1 - A$. However, on reducing investment by $1-\delta$ at the end of the period, the firm loses tax relief of $(1-\delta)\,A$, making the net saving equal to $(1-\delta)\,(1-A)$. The return of $p+\delta$ is taxes at the corporation tax rate τ. In the presence of tax, then, the present value of the income becomes

$$V = \{(p+\delta)\,(1-\tau) + (1-\delta)\,(1-A)\}\,/\,(1+r) \tag{C.1}$$

Equating V and C, and solving for the cost of capital in the presence of tax, denoted $\tilde{p}$, implies:

$$\tilde{p} = \frac{(1-A)}{(1-\tau)}\,(r+\delta) - \delta \tag{C.2}$$

As shown above, the cost of capital and the EMTR - defined as $(\tilde{p} - r)\,\tilde{p}$ - are the relevant measures for investigating tax competition in the second model described above.

In the first model each multinational chooses where to locate a single plant. Fixed costs prohibit more than one plant. The multinational expects to earn a positive economic rent, at least pre-tax. In this case, we consider the pre-tax rate of return to be fixed - say at p^*- and compute the net present value , or economic rent, of the investment. The pre-tax NPV is

$$NPV^* = -1 + \frac{1+p^*}{1+r} = \frac{p^* - r}{1+r} \tag{C.3}$$

and the post-tax NPV is

$$NPV = V - C = -(1-A) + \frac{(p^* + \delta)(1-\tau) + (1-\delta)(1-A)}{1+r} \tag{C.4}$$

Clearly, the difference between these two values is the NPV of tax payments. The impact of tax on the location decision in this case depends on the relative size of these tax payments across jurisdictions. Scaling by the NPV of pre-tax gross income generates the measure of the effective average tax rate (EATR) proposed by Devereux and Griffith (2002)[30]:

$$EATR = \frac{NPV^* - NPV}{p^*/(1+r)} \tag{C.5}$$

Devereux and Griffith demonstrate that this measures encompasses a complete range of effective tax rates. That is, the EATR is a weighted average of the EMTR and the statutory tax rate, where the weights depend on $p^*/\widetilde{p}$, ie:

$$EATR = \frac{p^*}{\widetilde{p}} EMTR + \left(1 - \frac{p^*}{\widetilde{p}}\right)\tau \tag{C.6}$$

Hence, for a marginal investment, $p^* = \widetilde{p}$ and hence $EATR = EMTR$. At the other extreme, as $p^* \rightarrow \infty$, then $EATR \rightarrow \tau$.

It is straightforward to add other elements into this comparison. In particular, if the whole investment is financed by debt, the firm borrows the post-tax cost of the investment. It repays this with interest in the following period, and receives tax relief for the interest paid. Details can be found in Devereux and Griffith (2002). Both forms of effective tax rate therefore depend on the source of finance. They also depend on the type of asset purchased, through the depreciation rate and the generosity of the allowance. We do not here incorporate personal taxes into the analysis. Neither do we allow for cross border investment, potentially taxed by both the home and host countries. A detailed comparison of these effective tax rates for the majority of countries included in the sample used in this paper is shown in Devereux, Griffith and Klemm (2002).

[30] Devereux and Griffith (2002) also discuss alternative ways of scaling tax payments.

TABLE 2 STATUTORY TAX RATE

	Contemporaneous model				Lagged Model			
Explanatory Variables	I Unweighted	II Distance Weighted	III GDP weighted	IV FDI weighted	V Unweighted mean	VI Distance Weighted	VII GDP weighted	VIII FDI weighted
$T_{i,t-1}$	0.498*** (0.10)	0.525*** (0.10)	0.635*** (0.08)	0.580*** (0.09)	0.511*** (0.11)	0.499*** (0.10)	0.604*** (0.09)	0.550*** (0.10)
A_{it}	0.297** (0.12)	0.143 (0.08)	0.196** (0.08)	0.147* (0.08)				
$D_{it}*A_{it}$	0.375*** (0.14)	0.352*** (0.13)	0.399* (0.21)	0.330** (0.142)				
D_{it}	-0.147*** (0.05)	-0.145*** (0.05)	-0.195* (0.10)	-0.142** (0.05)				
$A_{i,t-1}$					0.023 (0.12)	0.038 (0.08)	0.170* (0.09)	0.130*** (0.07)
$D_{i,t-1}*A_{i,t-1}$					0.314** (0.15)	0.348** (0.14)	0.295 (0.26)	0.316** (0.13)
$D_{i,t-1}$					-126** (0.05)	-0.140** (0.05)	-0.145 (0.12)	-0.133** (0.05)
$PYOU_{it}$	-0.695 (0.45)	-0.700 (0.44)	-1.184** (0.50)	-1.218** (0.513)	-0.377 (0.43)	-0.446 (0.42)	-0.754 (0.46)	-1.081** (0.49)
$POLD_{it}$	0.829 (0.52)	0.524 (0.53)	0.248 (0.56)	-0.025 (0.55)	0.396 (0.54)	0.345 (0.54)	0.059 (0.57)	0.079 (0.56)
$PURB_{it}$	0.479* (0.27)	0.451* (0.26)	0.273 (0.29)	0.280 (0.29)	0.6000** (0.28)	0.533* (0.27)	0.474 (0.29)	0.414 (0.28)
$SIZE_{it}$	0.733*** (0.24)	0.635*** (0.23)	0.712*** (0.26)	0.615*** (0.23)	0.451* (0.24)	0.516** (0.23)	0.600** (0.26)	0.573** (0.23)
$OPEN_{it-1}$	0.065 (0.04)	0.088* (0.05)	0.071 (0.05)	0.050 (0.04)	0.079 (0.05)	0.057 (0.05)	0.060 (0.05)	0.045 (0.04)
$TOPINC_{it}$	0.136*** (0.03)	0.129*** (0.04)	0.117*** (0.03)	0.109*** (0.03)	0.160*** (0.04)	0.146*** (0.04)	0.119*** (0.036)	0.123*** (0.03)
$PCON_{it}$	-0.008 (0.18)	-0.126 (0.18)	-0.165 (0.17)	-0.218 (0.18)	-0.146 (0.17)	-0.157 (0.17)	-0.167 (0.17)	-0.192 (0.18)
country fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
individual time trend	yes	yes	yes	yes	yes	yes	yes	yes
R^2	0.953	0.953	0.953	0.952	0.951	0.951	0.951	0.952
LM serial	0.432	0.946	0.025	0.029	0.053	0.018	0.100	0.193
LM spatial	0.002	0.000014	0.00019	0.000025	0.00006	0.000005	0.00025	0.000015
Observations	357	357	357	357	357	357	357	357

TABLE 3 EATR
Investment in buildings financed by retained earnings

Explanatory Variables	Contemporaneous model I Unweighted	II Distance Weighted	III GDP weighted	IV FDI weighted	Lagged Model V Unweighted mean	VI Distance Weighted	VII GDP weighted	VIII FDI weighted
$T_{i,t-1}$	0.499*** (0.10)	0.488*** (0.10)	0.441*** (0.09)	0.510*** (0.09)	0.505*** (0.10)	0.486*** (0.10)	0.491*** (0.10)	0.508*** (0.11)
A_{it}	0.345*** (0.12)	0.254*** (0.08)	0.188* (0.10)	0.254** (0.11)				
$D_{it}*A_{it}$	0.520*** (0.19)	0.422*** (0.13)	0.971** (0.38)	0.801*** (0.27)				
D_{it}	-0.189*** (0.07)	-0.153*** (0.04)	-0.373** (0.16)	-0.302*** (0.10)				
$A_{i,t-1}$					0.035 (0.13)	0.054 (0.074)	0.052 (0.15)	0.140 (0.14)
$D_{i,t-1}*A_{i,t-1}$					0.375** (0.17)	0.359*** (0.12)	1.0107** (0.45)	0.711*** (0.26)
$D_{i,t-1}$					-0.137** (0.06)	-0.129*** (0.04)	-0.451** (0.19)	-0.275*** (0.10)
$PYOU_{it}$	-0.957** (0.48)	-0.883* (0.48)	-1.587*** (0.56)	-1.442*** (0.54)	-0.646 (0.50)	-0.736 (0.50)	-1.372*** (0.52)	-1.305** (0.51)
$POLD_{it}$	1.321*** (0.50)	0.788 (0.48)	0.287 (0.49)	0.715 (0.45)	0.831 (0.53)	0.313 (0.51)	0.404 (0.51)	0.524 (0.47)
$PURB_{it}$	0.449* (0.26)	0.331 (0.26)	0.293 (0.26)	0.220 (0.27)	0.549** (0.27)	0.519** (0.25)	0.440* (0.25)	0.448* (0.25)
$SIZE_{it}$	0.782*** (0.21)	0.720*** (0.19)	0.740*** (0.24)	0.838*** (0.24)	0.484** (0.20)	0.508*** (0.19)	0.713*** (0.23)	0.603*** (0.20)
$OPEN_{it-1}$	0.048 (0.05)	0.072 (0.04)	0.088* (0.04)	0.069 (0.04)	0.071 (0.05)	0.077 (0.05)	0.080 (0.05)	0.055 (0.05)
$TOPINC_{it}$	0.111*** (0.03)	0.092** (0.03)	0.083** (0.03)	0.082** (0.03)	0.138*** (0.03)	0.120*** (0.03)	0.111*** (0.03)	0.118*** (0.03)
$PCON_{it}$	0.007 (0.16)	-0.010 (0.16)	-0.047 (0.16)	-0.036 (0.16)	-0.060 (0.15)	-0.047 (0.16)	-0.072 (0.16)	-0.080 (0.16)
country fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
individual time trend	yes	yes	yes	yes	yes	yes	yes	yes
R^2	0.947	0.947	0.950	0.949	0.944	0.945	0.946	0.946
LM serial	0.241	0.054	0.083	0.063	0.084	0.018	0.245	0.008
LM spatial	0.002	0.0000362	0.00005	0.000069	0.000001	0.0000249	0.00006	0.000016
Observations	357	357	357	357	357	357	357	357

TABLE 4 EMTR
Investment in buildings financed by retained earnings

	Contemporaneous model				**Lagged Model**			
Explanatory Variables	I Unweighted	II Distance Weighted	III GDP weighted	IV FDI weighted	V Unweighted mean	VI Distance Weighted	VII GDP weighted	VIII FDI weighted
$T_{i,t-1}$	0.541*** (0.12)	0.472*** (0.12)	0.544*** (0.09)	0.562*** (0.10)	0.579*** (0.116)	0.512*** (0.11)	0.573*** (0.10)	0.563*** (0.11)
A_{it}	0.309** (0.13)	0.315*** (0.09)	0.274** (0.12)	0.133 (0.14)				
$D_{it}*A_{it}$	0.716*** (0.24)	2.269*** (0.64)	1.799*** (0.62)	1.723*** (0.60)				
D_{it}	-0.397*** (0.13)	-0.826*** (0.23)	-1.231*** (0.46)	-1.067*** (0.38)				
$A_{i,t-1}$					0.165 (0.15)	0.121 (0.08)	0.120 (0.17)	0.104 (0.19)
$D_{i,t-1}*A_{i,t-1}$					-0.006 (0.02)	0.438*** (0.16)	0.763 (0.64)	-0.496 (0.57)
$D_{i,t-1}$					0.006 (0.01)	-0.260*** (0.09)	0.537 (0.47)	0.338 (0.38)
$PYOU_{it}$	-2.521 (1.78)	-2.963 (1.84)	-4.917** (1.98)	-2.774 (1.82)	-1.350 (1.83)	-1.592 (1.833)	-1.798 (1.82)	-1.622 (1.88)
$POLD_{it}$	3.395* (1.81)	3.244* (0.1.75)	1.319 (1.83)	2.821 (1.76)	2.388 (1.93)	2.724 (1.81)	2.085 (1.83)	1.424 (1.81)
$PURB_{it}$	0.660 (0.79)	1.230 (0.78)	0.267 (0.77)	1.051 (0.71)	1.821** (0.85)	1.700* (0.79)	1.444** (0.72)	1.868** (0.85)
$SIZE_{it}$	2.231*** (0.73)	2.294*** (0.74)	2.049** (0.85)	2.401** (0.94)	0.846 (0.71)	1.503** (0.73)	1.156 (0.79)	0.180 (0.75)
$OPEN_{it-1}$	0.197 (0.13)	0.209 (0.12)	0.261* (0.13)	0.225 (0.14)	0.215 (0.18)	0.222 (0.15)	0.254 (0.16)	0.233 (0.170
$TOPINC_{it}$	0.301*** (0.10)	0.270** (0.10)	0.264** (0.10)	0.337*** (0.10)	0.396*** (0.13)	0.360*** (0.126)	0.403*** (0.131)	0.394*** (0.12)
$PCON_{it}$	0.863 (0.58)	0.424 (0.50)	0.709 (0.57)	0.629 (0.55)	0.606 (0.55)	0.445 (0.52)	0.689 (0.55)	0.397 (0.52)
country fixed effects	yes	yes	yes	yes	yes	Yes	yes	Yes
individual time trend	yes	yes	yes	yes	yes	Yes	yes	Yes
R^2	0.927	0.928	0.931	0.927	0.919	0.922	0.920	0.919
LM serial	0.0233	0.134	0.745	0.0005	0.072	0.057	0.00015	0.0001
LM spatial	0.000012	0.0000303	0.0022	0.00022	0.0002	0.000014	0.00013	0.00044
Observations	357	357	357	357	357	357	357	357

TABLE 5 EATR and EMTR WEIGHTED AVERAGE
Contemporaneous model
Weights: Investment in buildings 36%, investment in Plant and Machinery 64%, financed by Retained Earnings 65%, financed by Debt 35%

	EATR				EMTR			
Explanatory Variables	I Unweighted	II Distance Weighted	III GDP weighted	IV FDI weighted	V Unweighted mean	VI Distance Weighted	VII GDP weighted	VIII FDI weighted
$T_{i,t-1}$	0.559*** (0.12)	0.519*** (0.12)	0.491*** (0.10)	0.535*** (0.11)	0.677*** (0.11)	0.611*** (0.11)	0.665*** (0.11)	0.679*** (0.10)
A_{it}	0.249 (0.17)	0.204** (0.08)	0.159 (0.12)	0.061 (0.122)	0.051 (0.27)	0.261** (0.10)	0.743*** (0.23)	0.552*** (0.19)
$D_{it}*A_{it}$	0.419** (0.20)	0.322** (0.14)	0.619* (0.34)	0.619*** (0.22)	1.517*** (0.58)	0.995* (0.55)	-0.358 (0.57)	-0.586** (0.25)
D_{it}	-0.125** (0.05)	-0.092** (0.07)	-0.184* (0.10)	-0.181*** (0.06)	-0.254*** (0.09)	-0.286* (0.15)	0.065 (0.10)	0.079** (0.03)
$PYOU_{it}$	-0.762** (0.36)	-0.814** (0.37)	-1.215*** (0.41)	-1.229*** (0.41)	-0.973 (0.74)	-1.431* (0.80)	-1.018 (0.78)	-0.900 (0.79)
$POLD_{it}$	0.631 (0.38)	0.426 (0.20)	0.292 (0.40)	0.389 (0.37)	1.699* (0.92)	1.333 (0.86)	1.161 (0.91)	1.050 (0.89)
$PURB_{it}$	0.360* (0.20)	0.376* (0.20)	0.255 (0.21)	0.248 (0.20)	-0.074 (0.39)	0.367 (0.34)	0.175 (0.37)	0.501 (0.37)
$SIZE_{it}$	0.553*** (0.15)	0.475*** (0.14)	0.572*** (0.18)	0.577*** (0.17)	0.245 (0.26)	0.215 (0.28)	-0.041 (0.24)	-0.005 (0.24)
$OPEN_{it-1}$	0.037 (0.04)	0.048 (0.04)	0.052 (0.04)	0.064* (0.03)	0.037 (0.06)	0.045 (0.06)	0.096 (0.07)	0.066 (0.07)
$TOPINC_{it}$	0.094*** (0.03)	0.084*** (0.03)	0.076*** (0.02)	0.083*** (0.02)	0.141** (0.05)	0.102** (0.05)	0.151** (0.06)	0.162** (0.06)
$PCON_{it}$	-0.153 (0.12)	-0.167 (0.12)	-0.184 (0.13)	-0.179 (0.12)	0.097) (0.20)	0.025 (0.20)	0.116 (0.21)	0.003 (0.20)
country fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
individual time trend	yes	yes	yes	yes	yes	yes	yes	yes
R^2	0.940	0.940	0.941	0.941	0.920	0.918	0.917	0.917
LM serial	0.54	0.137	0.051	0.090	0.596	1.138	1.215	2.78
LM spatial	0.0012	0.0000025	0.0093	0.0041	0.00014	0.00011	0.00017	0.0002
Observations	357	357	357	357	357	357	357	357

Figure 1. Development of Tax Rates
unweighted mean across countries of weighted average rates