Tax Rate and Tax Base Competition for Foreign Direct Investment

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Abstract

This paper argues that the changes in corporate tax rates and tax bases in the developed countries over the last decades are consistent with tougher international competition for foreign direct investment (FDI). We develop a model in which governments compete for FDI using corporate tax rates and depreciation allowances, and estimate the policy reaction functions with panel data for 43 developed countries and emerging markets. Using these estimated reaction functions we carry out simulations to investigate possible causes of the increase in tax competition.

1 Introduction

Corporate tax systems in the developed countries have undergone dramatic changes over the past decades as statutory tax rates have dropped and tax bases have gradually widened. We argue that these changes are consistent with tougher competition specifically for foreign direct investment (FDI). We make our case in three steps. First, we develop a model in which countries set both corporate tax rates and bases to compete for FDI. This model generates testable predictions concerning the slope of policy reaction functions with regard to the tax rate and the tax base, and links changes in equilibrium tax rates and bases to observable industry and country characteristics. Second, we use data on corporate tax systems in 43 countries (OECD members plus a number of emerging markets) to estimate policy reaction functions and test the model's comparative static predictions. Third, we apply the estimated reaction functions to quantify the role that market integration and other factors have played in boosting tax competition and changing the tax system.

Median statutory tax rates in our sample of industrialized countries and emerging markets have drastically declined to less than 30% in 2005 from around 50% in the early 1980s. At the same time, the tax base has become somewhat broader, as reflected in a gradual decrease in depreciation allowances (see Figure 1). The overall effect, as confirmed by Devereux et al. (2002) for OECD countries, has been a reduction in the effective average tax rate since the early 1980s, while the effective marginal tax rate has remained more or less stable. This downward trend in the effective average tax rate is consistent with more intense competition for mobile multinational enterprises , since the profitability of a plant location depends on the average rather than the marginal rate. Tougher tax competition for portfolio capital, by contrast, would have suggested a fall in the effective marginal tax rate (see Devereux et al., 2002).

−− Figure 1 −−

Table 1 reports the annual contemporary changes in tax rates and depreciation allowances. If every country in our sample had changed its tax rate and depreciation allowance each year, we would observe 749 changes in each instrument in total. Clearly, countries alter these instruments much less frequently. As for tax rates, we observe that they declined in 173, but increased in only 52 cases. In 524 cases the tax rate stayed the same. Changes in depreciation allowances are even rarer: they decreased in 52, increased in 56 and remained constant in 641 cases. These contemporary changes in policy instruments, however, do not tell us much about the nature of the strategic interactions, if any, that take place between countries. More revealing in this respect is a look at the unconditional correlations in domestic and foreign tax instruments, reported in Table 2.[1] Foreign and domestic tax rates are positively correlated, as are foreign and domestic depreciation allowances. However, foreign (domestic) tax rates and domestic (foreign) depreciation allowances are negatively correlated. A lower foreign tax rate is thus associated with a lower domestic tax rate but a higher domestic depreciation allowance. This suggests that countries might react to a fall in their competitors' tax rates by cutting their own tax rates and narrowing their tax base. What could be the reason?

−− Table 1 −−

The current paper offers a simple explanation for these stylized facts based on competition for discrete investment projects by multinational enterprises. Welfare-maximizing governments face two basic distortions when dealing with foreign multinationals. First, profit-seeking multinationals typically have market power and thus produce too little output from the point of

[1]Foreign tax instruments are computed as the weighted average of instruments for each country's competitors. Weights are based on potential (predicted) bilateral goods trade flows. All regressions include country fixed effects but no other covariates. Standard errors are robust to heteroskedasticity and serial correlation. Correlations should not be interpreted as reaction function parameters, since lacking fundamentals lead to inconsistent Nash tax rates.

view of social welfare; investment into their projects is likely to be suboptimal. Second, profits not captured by source-based taxation may be repatriated to foreign owners. To reduce these distortions a welfare-maximizing government will implicitly subsidize capital through a low effective marginal tax rate and capture a share of the multinationals' profits by making its effective average tax rate as high as possible without deterring the projects. When a rival reduces its tax rate or grants a more generous depreciation allowance, the best response of the government is to reduce the effective average tax rate while keeping the effective marginal tax rate constant. This can be achieved by lowering the corporate tax rate while increasing the depreciation allowance. Our model thus generates the observed negative correlation between changes in tax rates and depreciation allowances in response to shocks in the degree of competition for FDI. Our empirical analysis shows that this best-response pattern of countries is confirmed by the data.

−− Table 2 −−

By simultaneously considering changes in tax rates and depreciation allowances our paper refines the classical literature on tax competition, in which tax rates are the only policy instrument (see Wilson (1999) and Wilson and Wildasin (2004) for surveys of the literature). Another deviation from this literature is the focus on competition for discrete investment projects, which seems appropriate given the observed fall in effective average tax rates and stability of effective marginal tax rates. Of course, ours is not the only attempt to better reconcile the theory and empirics of tax competition with the stylized facts. Closely related papers are by Haufler and Schjelderup (2000) as well as Devereux et al. (2008), which also feature governments that compete for FDI using tax rates and depreciation allowances.[2] These two papers offer an explanation for the change in corporate tax systems that is complementary to ours. They argue that countries are forced to reduce corporate

[2]See also Becker and Fuest (2007), and Osmundsen et al. (1998). In these two papers, governments set tax rates and depreciation allowances to discriminate between firms with different productivity, resp. mobility costs. Janeba (1996) considers the use of tax rates and depreciation allowances to shift profits between domestic and foreign firms.

tax rates in response to attempts by multinational enterprises to use transfer pricing to shift profits to the lowest-tax location. Countries simultaneously reduce depreciation allowances either because they face a fixed tax revenue requirement and need to make up for the loss of revenue stemming from the lower tax rate (Haufler and Schjelderup, 2000), or because they are large and want to strategically depress the world price of capital (Devereux et al., 2008). Both papers have in common that changes in tax rates and depreciation allowances are positively correlated, which is in contradiction to the stylized facts presented in Table 2 above.

The general mechanism that drives the competition in tax rates and depreciation allowances in our paper is related to the one developed by Davies and Ellis (2007) for competition in taxes and performance requirements. Each government uses its policy instruments to maximize the joint surplus available to itself and a multinational when the latter locates in the country. In the context of our model, this requires the government to boost output/investment by the multinational. Competition between countries then forces them to give up this surplus to the multinational. The observed changes in corporate tax systems, according to this mechanism, are hence the result of much tougher international tax competition for FDI.

The question is what drives this increase in competition. In our model, changes in the tax system are triggered, among other things, by market integration. We consider the location choice of a multinational firm that wants to establish a plant to supply goods to a region consisting of two countries, A and B. The location choice depends on the tax liability faced in each country, as well as geographic factors such as relative market size and transportation costs. Regional integration, modeled as a reduction in trade costs between the two countries, induces tougher competition in statutory tax rates. With corporate tax rates decreasing due to lower trade costs, depreciation allowances have to increase to keep the effective marginal tax rate unchanged.

This mechanism is in line with empirical evidence. Competition for FDI especially on an intra-regional basis is well documented, and there is some evidence that it has increased in line with regional integration [Bond and Guisinger (1985)]. Bénassy-Quéré et al. (2005) find that nominal and effective corporate tax rates in the EU have decreased in the process of European integration. According to UNCTAD [(1996), Table III.1], the use of fiscal incentives, such as tax holidays, to attract FDI has increased in Europe between the mid-1980s and early 1990s. The study reports a similar trend in the United States and Canada. The main objectives pursued with these incentives appear to be to stimulate FDI.[3]

The rest of the paper is organized as follows. Section 2 presents a simple model along the lines of Haufler and Wooton (1999), Raff (2004), and Bjorvatn and Eckel (2006), in which we can demonstrate the workings of our tax competition mechanism and derive testable predictions concerning the slope of reaction functions and comparative static effects. Section 3 derives a preliminary result that is useful in Section 4 where we characterize the Nash equilibrium taxes and depreciation allowances. Section 5 derives comparative static results, and Section 6 contains the empirical analysis. Section 7 concludes. The Appendix contains proofs and data sources.

2 Model

Consider a multinational firm that seeks to locate a production plant in a region consisting of two countries, labeled A and B. The multinational firm is owned by residents outside the region; any profit earned by the firm is repatriated to these owners. Households in A and B have identical preferences. Each household consumes two types of goods: the good supplied by

[3] Also note that there is considerable evidence that regional integration affects FDI flows. For instance, the creation of the European customs union in 1968 and especially the Single European Act of 1986/87 were associated with significant inflows of U.S. and Japanese FDI [see, for instance, Motta and Norman (1996) and Pain (1997)]. Similar effects were observed in the case of the North American Free Trade Agreement (NAFTA), which particularly boosted FDI into Mexico. Some authors, including Ethier (1998), have argued that attracting FDI was in fact one of the main reasons why some countries have pursued integration. Given the potential of regional integration to affect the location choices of foreign investors, it seems indeed plausible that governments have reacted by adapting their corporate tax systems.

the multinational, and a numeraire good that is competitively provided in each country. The utility function of a household residing in country $i = A, B$ is given by

$$U_i = q_i - \frac{1}{2}q_i^2 + z_i, \tag{1}$$

where q_i and z_i denote the consumption of the multinational's good and the numeraire, respectively.

Capital is the only factor of production, and technologies are identical across countries. Production of a unit of the numeraire good requires exactly one unit of capital. Hence the price of capital is equal to one in both countries. The numeraire good can be transported freely across countries, so that trade is always balanced. Production of the multinational's good requires $c < 1$ units of capital per unit of output, so that c can be interpreted as the marginal cost of production.[4] It is implicitly assumed that there is a sufficiently large set-up cost for a plant (relative to the cost of transporting goods between A and B) so that it does not pay the multinational to have a plant in each country; rather, the multinational will choose one location from which to supply the whole region. To be consistent with this assumption we let the per-unit trade cost between countries, denoted by s, be sufficiently small to guarantee positive exports, i.e., $s < 1 - c$.

Households inelastically supply one unit of capital each. Denoting the consumer price of the multinational's good in country i by p_i , per-capita tax revenue (revenue is redistributed by the government in lump-sum fashion) by R_i, a household's budget constraint is

$$p_i x_i + z_i = 1 + R_i. \tag{2}$$

Maximizing utility subject to the budget constraint yields the household's demand in country i

$$q_i = 1 - p_i. \tag{3}$$

[4]Rather than endowing countries with identical technologies, we could assume that the multinational brings its technology with it. This, too, would assure that the multinational faces the same marginal cost in both countries.

We assume that country A has a measure $n \geq 1$ of households, whereas the measure of households in B is normalized to one. Denoting total sales in country i by Q_i we can write inverse market demand in the two countries as

$$p_A = 1 - \frac{Q_A}{n} \quad \text{and} \quad p_B = 1 - Q_B. \tag{4}$$

Markets in the two countries are segmented so that the multinational can set prices independently in each market.

The governments of A and B choose tax policy to maximize the utility of the households under their jurisdiction, or social welfare for short. Social welfare consists of the sum of tax revenue and consumer surplus. Each government has two policy instruments: a source-based corporation tax on profits, where t denotes country A's and τ country B's statutory tax rate; and a depreciation allowance d (δ) in the case of country A (B) that determines the tax base. Hence the tax paid by the multinational when it locates a plant in country A and sells its output in A and B is

$$t\left[\left(1 - \frac{Q_A}{n} - dc\right) Q_A + (1 - Q_B - dc - s)\, Q_B\right],$$

and the corresponding after-tax profit of the multinational is equal to

$$\begin{aligned} \Pi^A &= (1-t)\left[\left(1 - \frac{Q_A}{n}\right) Q_A + (1 - Q_B - s)\, Q_B - c(Q_A + Q_B)\right] \\ &\quad -(1-d)tc(Q_A + Q_B). \end{aligned} \tag{5}$$

It turns out to be convenient to rewrite this function in terms of the effective marginal tax rate ($EMTR$) on capital, $a - 1$, which we define as follows:

$$a - 1 \equiv \frac{(1-d)\,t}{1-t} = \frac{1-dt}{1-t} - 1. \tag{6}$$

Hence we obtain

$$\begin{aligned} \Pi^A &= (1-t)\left[\left(1 - \frac{Q_A}{n}\right) Q_A + (1 - Q_B - s)\, Q_B - c(Q_A + Q_B)\right] \\ &\quad -(a-1)(1-t)c(Q_A + Q_B) \\ &= (1-t)\left[\left(1 - \frac{Q_A}{n}\right) Q_A + (1 - Q_B - s)\, Q_B - ac(Q_A + Q_B)\right]. \end{aligned} \tag{7}$$

The corporation tax is hence equivalent to a pure profit tax, if $d = 1$ and therefore $a = 1$. If $d > 1$ ($a < 1$), more than the true capital cost can be deducted for tax purposes; hence capital use in production is implicitly subsidized ($EMTR < 0$). If $d < 1$ ($a > 1$), the taxable cost is less than the actual cost, and the capital input is implicitly taxed ($EMTR > 0$). In the following we will work with a (α) instead of d (δ). However, given the statutory tax rate and the $EMTR$ we can easily compute d (δ).

The reason why the governments will want to use two instruments to tax the firm is that there are two "distortions": (i) the multinational is owned by foreign residents and will repatriate its profit unless the government captures this profit with a tax; and (ii) as a monopolist the multinational produces too little output, giving the government an incentive to subsidize production. Governments are assumed to be able to commit to the policies they announce. For instance, if country i offers a low corporate tax rate to attract investment, it does not rescind its offer once the firm has made its investment.[5] The strategic interaction between the governments and the firm can be represented by a sequential game with the following order of moves:

Stage 1: A and B choose their policy instruments simultaneously and non-cooperatively.

Stage 2: The firm observes these policies and decides in which country to locate.

Stage 3: The firm chooses output for each country.

We seek to characterize the pure-strategy subgame-perfect equilibria of this game (equilibria for short). A useful first step is to examine policy responses if the multinational's location is fixed. These policies can then serve as a reference point for the derivation of the equilibrium policies.

[5] The commitment problem and its effect on FDI has been extensively discussed in the literature [see, for instance, Bond and Samuelson (1988), and Doyle and van Wijnbergen (1994)]. The current paper has nothing new to add to this literature. We avoid the commitment problem by abstracting from sunk investment costs.

3 Optimal Policies for Fixed Locations

Suppose that the multinational locates a plant in A. The after-tax profit generated by selling its output in both A and B is given by (7). The profit-maximizing output choices are

$$Q_A = \frac{n(1-ac)}{2}, \text{ and } Q_B = \frac{(1-ac-s)}{2},$$

which implies consumer surplus in A and B of:

$$S^A = \frac{n(1-ac)^2}{8}, \text{ and } S^B = \frac{(1-ac-s)^2}{8}.$$

The maximized after-tax profit is given by:

$$\hat{\Pi}^A = (1-t)\frac{n(1-ac)^2 + (1-ac-s)^2}{4}. \tag{8}$$

Taking into account the implicit subsidy/tax on the multinational's output, the tax revenue accruing to A is equal to:

$$t\frac{n(1-ac)^2 + (1-ac-s)^2}{4} - \frac{(1-a)c\,(n(1-ac) + (1-ac-s))}{2}. \tag{9}$$

Now it is straightforward to compute the social welfare of country A, which equals the sum of consumer surplus and tax revenue:

$$W^A(a,t) = \frac{n(1-ac)^2}{8} + t\frac{n(1-ac)^2 + (1-ac-s)^2}{4} - \frac{(1-a)c\,(n(1-ac) + (1-ac-s))}{2}.$$

The government maximizes this function subject to the multinational's participation constraint. Assuming that the firm requires a minimum profit of $k \geq 0$, the participation constraint becomes:

$$(1-t)\frac{n(1-ac)^2 + (1-ac-s)^2}{4} \geq k. \tag{10}$$

The participation constraint has to be binding at the optimum so that we can use it to eliminate t in the welfare function:

$$W^A(a) = \frac{n(1-ac)^2}{8} + \frac{n(1-ac)^2 + (1-ac-s)^2}{4} - \frac{(1-a)c\,(n(1-ac) + (1-ac-s))}{2} - k.$$

Maximization with respect to a yields:

$$a^* = \frac{(2c - n + 2cn)}{(n+2)\,c}. \tag{11}$$

Note that $a^* - 1 < 0$ so that the optimal EMTR is negative. That is, the government implicitly subsidizes investment to reduce the monopoly distortion and increase consumer surplus.[6] More importantly, the government optimally responds to an increase in the multinational's outside profit by keeping a unchanged and reducing t to satisfy the participation constraint.

4 Equilibrium Policies

In this section we characterize the countries' best response functions and the Nash equilibrium tax policies. Consider the multinational's location choice for given tax policies in A and B. The multinational will choose to locate in A, if the profit of locating there exceeds the profit of locating in B:

$$(1-t)\,\frac{n\,(1-ac)^2 + (1-ac-s)^2}{4} \geq (1-\tau)\,\frac{(1-\alpha c)^2 + n\,(1-\alpha c - s)^2}{4} \tag{12}$$

Note that (12) is a generalization of the multinational's participation constraint (10). If country B lowers τ and/or lowers α, so that the profit the firm may earn when locating in B rises, A's government is forced to adjust its policies to keep the firm from relocating. Moreover, since social welfare is strictly increasing in t, A will make sure that the multinational's participation contstraint is always binding. Obviously, the same reasoning applies to country B, so that the multinational's participation constraint will hold simultaneously in both countries for given levels of a and α.

This makes computing the Nash equilibria of the game simple, because we know from the preceding section that a binding participation constraint

[6] Since part of the output is exported to B, the subsidy falls short of the level needed to reduce the domestic price in A to marginal cost c. However, it is easy to show that if the trade cost is prohibitive so that the entire subsidy falls on local output, the optimal implicit subsidy, $a^* = (2c-1)/c$, indeed induces the multinational to set a price equal to c.

implies that a country has an optimal level of a (α) that is independent of its profit tax. Hence in the Nash equilibrium A will choose $a = a^*$, and B will set $\alpha = \alpha^*$, where

$$a^* = \frac{2c - n + 2cn}{(n+2)\,c} \text{ and } \alpha^* = \frac{2c + 2cn - 1}{(1+2n)c}. \tag{13}$$

Using $a = a^*$ and $\alpha = \alpha^*$ in (12) implicitly defines the two countries' best response functions:

$$(1-t)\,\frac{n\,(1-a^*c)^2 + (1-a^*c-s)^2}{4} - (1-\tau)\,\frac{(1-\alpha^*c)^2 + n\,(1-\alpha^*c-s)^2}{4} = 0. \tag{14a}$$

These best response functions obviously have a positive slope, meaning that corporate tax rates are strategic complements. To compute the equilibrium, note that given the rival's corporate tax rate, each country will try to lower its corporate tax rate just enough to attract the multinational. For $s > 0$ and $n > 1$, A has a locational advantage relative to B, since with identical policies and positive trade costs the multinational prefers to locate in the larger market. It is easily verified that in equilibrium, the government of B chooses the τ that makes it just indifferent between attracting the multinational and having it locate in A. A's government sets t so as to attract the multinational and extract the locational rent.[7]

That is, B's government chooses τ so that welfare (consisting of the sum of consumer surplus and tax revenue) when the firm locates in B is just equal to welfare (i.e., the consumer surplus from importing the good) when the firm is located in A:

$$\frac{(1-\alpha^*c)^2}{8} + \tau\frac{(1-\alpha^*c)^2 + n\,(1-\alpha^*c-s)^2}{4} - \frac{(1-\alpha^*)c\,((1-\alpha^*c) + n\,(1-\alpha^*c-s))}{2} = \frac{(1-a^*c-s)^2}{8} \tag{14b}$$

[7] Determining the equilibrium profit taxes is thus equivalent to computing a Nash equilibrium in a Bertrand competition game between firms producing homogeneous goods with different constant marginal costs.

Thus B's equilibrium tax is given by a function $\tau^* = \tau^*(c, n, s)$. A's government sets t such that the multinational is indifferent between locating in A or in B. The equilibrium value of t can be computed from (14) by setting $\tau = \tau^*$. We denote the equilibrium tax rate by $t^* = t^*(c, n, s)$.

Given the equilibrium levels of t and a (τ and α) we can use (6) to solve for the depreciation allowance d (δ). Since $a^* < 1$, we obtain for A

$$d^* = \frac{1 - a^*(1 - t^*)}{t^*} \begin{array}{l} > 1 \text{ for } t^* > 0 \\ < 1 \text{ for } t^* < 0 \end{array}. \tag{15}$$

Totally differentiating (6) we can derive how d^* has to be adjusted following changes in t^* so that a remains fixed at a^*, namely

$$\frac{dd^*}{dt^*} = \frac{1 - d^*}{t^*(1 - t^*)} < 0. \tag{16}$$

Similarly for B we can show that $\frac{d\delta^*}{d\tau^*} < 0$. That is, an increase in the statutory tax rate has to be accompanied by a reduction in the depreciation allowance to hold the $EMTR$ fixed at the opimal level.

We may summarize this discussion by stating the following testable hypotheses concerning the strategic relationship between A's and B's policy variables:

Hypothesis 1 Country A's (B's) statutory tax rate t (τ) is a strategic complement to B's (A's) statutory tax rate τ (t), and a strategic substitute to B's (A's) depreciation allowance δ (d).

Hypothesis 2 Country A's (B's) depreciation allowance d (δ) is a strategic substitute to B's (A's) tax rate τ (t), and a strategic complement to B's (A's) depreciation allowance δ (d).

These hypotheses follow directly from the fact that (i) statutory tax rates are strategic complements, and (ii) the depreciation allowance has to move in the opposite direction from the tax rate to keep the country's $EMTR$ at the optimal level. Hence if B (A) lowers its statutory tax rate or raises its depreciation allowance, thereby increasing the multinational's profit from locating there, A (B) will react by lowering its own statutory tax rate and raising its depreciation allowance.

5 Comparative Statics

Next, we investigate the properties of the Nash equilibrium. It is straightforward to obtain analytical solutions for $t^*(c, n, s)$ and $\tau^*(c, n, s)$, and to compute the partial derivatives of taxes and depreciation allowances with respect to c, n and s. But the expressions are complicated. To examine the comparative static properties of the Nash equilibrium we therefore proceed in two steps. First, we evaluate the partial derivatives for two special, but meaningful cases, namely $s = 0$ (free trade) and, separately, $n = 1$ (symmetric countries). For these two cases we can easily sign the derivatives. Second, we run simulations to verify that the signs are robust outside of these special cases.[8]

Consider how the equilibrium policies change with the trade cost. An increase in s makes country A a more attractive location for the multinational relative to B. This allows A to raise its tax rate for any given value of its rival's tax rate. In other words, A's best response function, (14), shifts outward. How B's equilibrium tax rate changes with s can be derived from (**??**). There are two opposing effects. First, an increase in s raises the consumer surplus when the firm locates in B relative to when it locates in A, which implies that B would ceteris paribus be willing to lower its tax rate to attract the firm. Second, an increase in s lowers the profit the firm can earn when locating in B; hence attracting the firm is only advantageous for B if it can levy a higher tax rate.

The second effect dominates when n is sufficiently big so that both A's and B's equilibrium tax rates are increasing in s. Market integration in the form of a marginal reduction in trade costs between the two countries thus leads

[8]Note that we can carry out these simulations for values of the trade cost between zero and the prohibitive level, so that we can indeed get a clear picture of the comparative static effects for the relevant range of trade costs.

to lower statutory tax rates. As tax rates decrease, depreciation allowances have to increase to keep the effective marginal tax rate unchanged, so as not to distort the investment/output choices of the firm. Formally, we can show that the derivatives at $s = 0$ take the following signs (see the Appendix for a proof)

$$\frac{\partial t^*}{\partial s} > 0, \frac{\partial \tau^*}{\partial s} > 0, \frac{\partial d^*}{\partial s} < 0, \frac{\partial \delta^*}{\partial s} < 0.$$

Simulations reported in the Appendix confirm that these signs are robust even for $s > 0$. We can thus formulate the following hypothesis:

Hypothesis 3 Assuming that s is sufficiently small and n is sufficiently big, a decrease in the trade cost reduces each country's statutory tax rate ($\frac{\partial t^*}{\partial s} > 0$, $\frac{\partial \tau^*}{\partial s} > 0$) and increases its depreciation allowance ($\frac{\partial d^*}{\partial s} < 0$, $\frac{\partial \delta^*}{\partial s} < 0$).

Since a fall in the trade cost reduces the attractiveness of country A as a plant location relatively to country B, one would expect tax rates in A and B to converge as markets are integrated. Depreciation allowances, on the other hand, should diverge so as to keep the EMTR in each country fixed. In the Appendix we prove that this is indeed the case for $s = 0$, which leads us to postulate the following hypothesis:

Hypothesis 4 Assuming that s is sufficiently small, a fall in the trade cost leads to a convergence of statutory tax rates ($\frac{\partial (t^* - \tau^*)}{\partial s} > 0$) and a divergence of depreciation allowances ($\frac{\partial (d^* - \delta^*)}{\partial s} < 0$).

Next, consider the comparative statics with respect to country size n. An increase in the size of country A relative to B increases the location rent that A can extract from the multinational through its tax rate, and worsens B's competitive position. Ceteris paribus, this would allow A to raise its tax rate, and force B to reduce its tax rate. Changes in n also affect the optimal EMTR. Using (13), we obtain $\frac{\partial (a^* - 1)}{\partial n} = -\frac{2(1-c)}{c(n+2)^2} < 0$ and $\frac{\partial (\alpha^* - 1)}{\partial n} = \frac{2(1-c)}{c(2n+1)^2} > 0$. Having a bigger market lowers A's optimal EMTR, and vice versa for B. Changes in equilibrium tax rates and depreciation allowances thus reflect both the changes in location rents and the changes in the optimal EMTR. We show formally in the Appendix that at $s = 0$ and assuming that n is sufficiently big

$$\frac{\partial t^*}{\partial n} > 0, \frac{\partial \tau^*}{\partial n} < 0, \frac{\partial d^*}{\partial n} > 0, \frac{\partial \delta^*}{\partial n} < 0.$$

Simulations for the partial derivatives with respect to n, also reported in the Appendix, indicate that $\frac{\partial t^*}{\partial n} > 0$ and $\frac{\partial \tau^*}{\partial n} < 0$ for a wide range of parameters. This leads us to postulate the following hypothesis:

Hypothesis 5 Assuming that s is sufficiently small and n is sufficiently big, an increase in the size of country A relative to that of B, raises the statutory tax rate in A ($\frac{\partial t^*}{\partial n} > 0$), and reduces the statutory tax rate in B ($\frac{\partial \tau^*}{\partial n} < 0$); it raises the depreciation allowance in A ($\frac{\partial d^*}{\partial n} > 0$), and reduces the depreciation allowance in B ($\frac{\partial \delta^*}{\partial n} < 0$).

Finally consider how the equilibrium policies react to changes in the marginal cost. An increase in c induces both countries to raise their EMTR, as $\frac{\partial(a^*-1)}{\partial c} = \frac{n}{c^2(n+2)} > 0$ and $\frac{\partial(\alpha^*-1)}{\partial c} = \frac{1}{c^2(2n+1)} > 0$. An increase in c also reduces the profitability of both investment locations and hence forces countries to adjust their tax rates. For $s = 0$ and n sufficiently big, we demonstrate in the Appenidx that $\frac{\partial t^*}{\partial c} = 0$, $\frac{\partial \tau^*}{\partial c} = 0$, $\frac{\partial d^*}{\partial c} < 0$, and $\frac{\partial \delta^*}{\partial c} < 0$. For $n = 1$ (symmetric countries) we find that $\frac{\partial t^*}{\partial c} < 0$ and $\frac{\partial d^*}{\partial c} < 0$ within the admissible range of s can c. This discussion is summarized in the following hypothesis:

Hypothesis 6 When s is sufficiently small and n is sufficiently big, or when countries are symmetric ($n = 1$) and s and c are sufficiently small, an increase in the marginal cost weakly reduces statutory tax rates and decreases the depreciation allowance ($\frac{\partial t^*}{\partial c} \leq 0$, $\frac{\partial \tau^*}{\partial c} \leq 0$, $\frac{\partial d^*}{\partial c} < 0$, and $\frac{\partial \delta^*}{\partial c} < 0$).

6 Empirical Analysis

6.1 Profit tax data features

We use an unbalanced panel data-set of 43 European and also non-European economies which covers the period 1983-2005.[9]

6.2 Specification

The theoretical model in Section 2 suggests that governments may use two instruments to compete for multinational plant location: statutory tax rates and depreciation allowances. The empirical data-set allows inference from panel data. Therefore, we use a time (year) index $y = 1, ..., Y$ to refer to a cross-section of countries in a specific period. Let us collect the determinants of the (Nash) equilibrium in these two instruments for year y into the $N \times K$ matrix $\mathbf{X}_y$, where N denotes the number of countries in the sample. According to the theoretical model, country size (n), production costs (c), and transportation costs (s) belong in $\mathbf{X}_y$. We approximate country size by the logarithm of a country's real GDP (using the year 2000 as the base year) and refer to the corresponding $N \times 1$ vector for all countries in year y as $\mathbf{n}_y$. Furthermore, we use the logarithm of GDP per capita as a measure of costs and collect the observations for year y into the $N \times 1$ vector $\mathbf{c}_y$. Finally, we approximate a country's trade costs by a trade barrier index which is annually published by the World Economic Forum.[10] We refer to the corresponding $N \times 1$ vector of trade costs for year y as $\mathbf{s}_y$. Furthermore, with

[9] Note that we refer to this data-set as a balanced panel even though some of the countries (namely the Central and Eastern European ones) are not included before the fall of the iron curtain. From the perspective of tax competition, the opening of the borders to both goods transaction as well as capital flows was equivalent to an increase in the 'size of the world' in terms of the number of relevant competitors. Hence, the rising cross-section over time entails a very specific kind of unbalancedness, reflecting the increase of world size in terms of the number of politically independent and at least partially integrated economies.

[10] For instance, this index has been employed as a measure of trade costs in Carr, Markusen, and Maskus (2001) and Markusen and Maskus (2002). We gratefully acknowledge provision of the data by Keith Maskus.

panel data we are able to control for a comprehensive set of time-invariant determinants by accounting for fixed country-specific effects. With matrix notation, for year y this involves an $N \times N$ identity matrix $\mathbf{I}_y$. With these definitions at hand, we may define $\mathbf{X}_y = [\mathbf{n}_y, \mathbf{c}_y, \mathbf{s}_y, \mathbf{I}_y]$ so that $K = 3 + N$. Note that the variables in $\mathbf{X}_y$ matter for the Nash equilibrium in both the $N \times 1$ vector of statutory tax rates $\mathbf{t}_y$ and that one of depreciation allowance parameters $\mathbf{d}_y$. However, the marginal effects of these variables (hence, the corresponding parameters in the econometric model) may differ. Let us refer to the $K \times 1$ vector parameters for statutory tax rates as $\boldsymbol{\delta}_t$ and to that one for depreciation allowances as $\boldsymbol{\delta}_d$.

Moreover and most importantly, strategic interaction among governments leads to interdependence in the setting of the two instruments. The empirical modeling of the corresponding surface faces two challenges: the domestic statutory tax rate ($\mathbf{t}_y$) is a function of the foreign statutory tax rate ($\boldsymbol{\tau}_y$) and the foreign depreciation allowance parameter ($\boldsymbol{\delta}_y$). Similarly, the domestic depreciation allowance parameter ($\mathbf{d}_y$) is a function of $\boldsymbol{\tau}_y$ and $\boldsymbol{\delta}_y$. Of course, with a data-set of more than two countries, for each country $\boldsymbol{\tau}_y$ and $\boldsymbol{\delta}_y$ reflect a weighted average of the tax parameters ($\mathbf{t}_y$) and ($\mathbf{d}_y$) of all other countries. Let us define an $N \times N$ weighting matrix $\mathbf{W}$ whose elements correspond to weights. Two important properties of $\mathbf{W}$ are that it contains zero diagonal elements and that its row sums are bounded, e.g., due to normalizing entries by their row-sum. Hence, domestic tax instruments are (strategically) related to average foreign ones. For instance, for country i the corresponding weighted average of foreign statutory tax rates in year y would be $\tau_{iy} = \mathbf{w}_i \mathbf{t}_y$, where $\mathbf{w}_i$ is a $1 \times N$ row vector of $\mathbf{W}$ whose elements sum up to unity. For all countries, we may write $\boldsymbol{\tau}_y = \mathbf{W}\mathbf{t}_y$. Similarly, we may write $\boldsymbol{\delta}_y = \mathbf{W}\mathbf{d}_y$. Let us refer to the slope parameters of the reaction function (with two instruments, we should refer to this as a surface) of $\mathbf{t}_y$ with respect to $\boldsymbol{\tau}_y$ as β_t and to that one of $\mathbf{d}_y$ with respect to $\boldsymbol{\delta}_y$ as β_d. Furthermore, let us denote the slope parameter of the reaction function of $\mathbf{t}_y$ with respect to $\boldsymbol{\delta}_y$ as γ_t and that one of the reaction function of $\mathbf{d}_y$ with respect to $\boldsymbol{\tau}_y$ as γ_d. Then the econometric model capturing profit tax competition in both $\mathbf{t}_y$ and $\mathbf{d}_y$ may be written as

$$\mathbf{t}_y = \beta_t \mathbf{W}\mathbf{t}_y + \gamma_t \mathbf{W}\mathbf{d}_y + \mathbf{X}_y \xi_t + \mathbf{u}_{t,y} \tag{17}$$

$$\mathbf{d}_y = \beta_d \mathbf{W}\mathbf{d}_y + \gamma_d \mathbf{W}\mathbf{t}_y + \mathbf{X}_y \xi_d + \mathbf{u}_{d,y}. \tag{18}$$

According to our theoretical model, we expect domestic and foreign statutory tax rates to be strategic complements ($\beta_t > 0$ by Hypotheses 1). Similarly, domestic and foreign depreciation allowances should be strategic complements ($\beta_d > 0$ by Hypothesis 2). Moreover, we hypothesize that the domestic statutory tax rate is a strategic substitute to the foreign depreciation allowance and vice versa ($\gamma_t < 0$ by Hypothesis 1; $\gamma_d < 0$ by Hypothesis 2). For the parameters of the country size variable, we expect $\xi_{1,t} > 0$ and $\xi_{1,d} > 0$ (because $\frac{\partial t^*}{\partial n} > 0$ and $\frac{\partial d^*}{\partial n} > 0$ by Hypothesis 5). Moreover, with costly trade and symmetric countries, for the parameters of the cost variable we expect $\xi_{2,t} < 0$ and $\xi_{3,d} < 0$, respectively (because $\frac{\partial t}{\partial c} < 0$ and $\frac{\partial d}{\partial c} < 0$ by Hypothesis 6). Finally, for the parameters of the trade cost variable, we expect $\xi_{3,t} > 0$ and $\xi_{3,d} < 0$ (because $\frac{\partial t^*}{\partial s} > 0$ and $\frac{\partial d}{\partial s} < 0$ by Hypothesis 3).

6.3 Methodology

Cross-sectional interdependence through the inclusion of $\mathbf{W}\mathbf{t}_y$ and $\mathbf{W}\mathbf{d}_y$ in (17) and (18) renders the least squares dummy variable estimator of the parameters (i.e., OLS with fixed country effects) inconsistent. This can be avoided by instrumental variable two-stage least squares (IV-2SLS) with instruments $\mathbf{W}\mathbf{X}_y$, $\mathbf{W}^2\mathbf{X}_y$, $\mathbf{W}^3\mathbf{X}_y$, etc., see Kelejian and Prucha, 1999). If the instruments are relevant and uncorrelated with the disturbances, IV-2SLS will be consistent. Yet, it still might be inefficient. The latter may be due to heteroskedastic and cross-sectionally and/or serially correlated disturbances $\mathbf{u}_{t,y}$ or $\mathbf{u}_{t,y}$. One may avoid efficiency losses by correcting the estimate of variance-covariance matrix, accordingly. We do so by employing a version of the variance-covariance matrix estimator for spatially and/or serially correlated data following Driscoll and Kraay (1998).

Note that our data-set covers the period $1982-2005$, hence, there are 24 consecutive periods. In this case, IV-2SLS with fixed country dummies obtains valid estimates not only of the parameters of the covariates but also of the fixed effects (and, hence, the disturbances $\mathbf{u}_{t,y}$ and $\mathbf{u}_{t,y}$).[11]

For the definition of the IV-2SLS GMM estimator and its heteroskedasticity and spatial as well as serial autocorrelation-consistent (HAC) estimator of the variance-covariance matrix in the spirit of Driscoll and Kraay (1998), it will be useful to introduce some further notation. Recall that we indicate countries by $i = 1, ..., N$ and time periods by $y = 1, ..., Y$. For convenience, let us use the running index $\ell = t, a$ to refer to the two equations (17) and (18), respectively. Furthermore, define the $N \times (K + 2)$ matrix $\mathbf{Z}_y = [\mathbf{Wt}_y, \mathbf{Wd}_y, \mathbf{X}_y]$ and refer to the $NY \times (K + 2)$ stacked version of this matrix (covering all years) as $\mathbf{Z}$. IV-2SLS potentially involves sets of instruments which differ across equations. Define the number of instruments in equation ℓ as $P_\ell \geq K + 2$ and collect the instruments for equation ℓ and all years into the $NY \times P_\ell$ matrix $\mathbf{D}$.[12] Then, we may define the projection $\hat{\mathbf{Z}} = \mathbf{D}(\mathbf{D}'\mathbf{D})^{-1}\mathbf{D}'\mathbf{Z}$. Later on, we will refer to one row of $\hat{\mathbf{Z}}$ by the $1 \times (K + 2)$ vector $\hat{\mathbf{z}}_{iy}$. Finally, collect the IV-2SLS parameters for equation ℓ into the $(K + 2) \times 1$ vector $\boldsymbol{\theta}_\ell$. Let us refer to the (inefficient) estimate of the $(K + 2) \times (K + 2)$ variance-covariance matrix of the parameters as $\hat{\mathbf{V}} = (\mathbf{Z}'\mathbf{D}_\ell\mathbf{D}_\ell'\mathbf{Z})^{-1}$.

Driscoll and Kraay (1998) suggest averaging the moment conditions to obtain $\mathbf{h}_y(\boldsymbol{\theta}_\ell) = \frac{1}{N}\sum_{i=1}^{N}\mathbf{h}_{iy}(\boldsymbol{\theta}_\ell)$. Let us use the notation $\mathbf{h}_{\ell y} = \mathbf{h}_y(\boldsymbol{\theta}_\ell)$ to write

$$\mathbf{h}_{\ell y} = \frac{1}{N}\sum_{i=1}^{N}\mathbf{d}_{\ell iy}\mathbf{u}_{\ell iy}; \quad \mathbf{h}_{\ell y'} = \frac{1}{N}\sum_{i=1}^{N}\mathbf{d}_{\ell iy'}\mathbf{u}_{\ell iy'}. \tag{19}$$

[11] With a very small number of periods but a large number of countries N, it would not be possible to obtain valid estimates of these residuals due to the relatively large number of fixed country effects.

[12] Of course, the $NY \times K$ matrix $\mathbf{X}$ of exogenous variables in (17) and (18) is part of $\mathbf{D}$.

with $y, y' = 1, ..., Y$. Furthermore, let us define the matrix

$$\mathbf{S}_{\ell Y} = \frac{1}{Y} \sum_{y=1}^{Y} \sum_{y'=1}^{Y} E[\mathbf{h}_{\ell y} \mathbf{h}'_{\ell y'}] \tag{20}$$

and note that $E[\mathbf{h}_{\ell y} \mathbf{h}'_{\ell y'}] = \frac{1}{N^2} \sum_{i=1}^{N} \mathbf{d}_{\ell iy} \mathbf{d}'_{\ell iy'} E[u_{\ell iy} u_{\ell iy'}]$.

A HAC estimator of the variance-covariance matrix with IV-2SLS in the spirit of Driscoll and Kraay (1998) is then defined as

$$\hat{\mathbf{V}}_{HAC} = (\mathbf{Z}' \mathbf{D}_{\ell} \hat{\mathbf{S}}_{\ell Y}^{-1} \mathbf{D}'_{\ell} \mathbf{Z})^{-1}. \tag{21}$$

Driscoll and Kraay (1998) prove that such a Newey and West (1987)-type estimator of the variance-covariance matrix relies on fairly weak assumptions.

6.4 Results

We summarize IV-2SLS parameter estimates in the benchmark models for statutory tax rates and depreciation allowances in Table 3. With each of the models, we report two sets of standard errors: ones that are based on the Huber-White sandwich estimator of the variance-covariance matrix (ignoring any spatial or serial correlation) and ones that are based on the above described SHAC estimator (considering serial correlation of the disturbances with their counterparts in up to three periods in the past).

−− Table 3 −−

Let us briefly describe the general model characteristics before turning to the parameter estimates. First of all, the explanatory power of the second stage models is generally high. As expected, country-specific characteristics are important and abandoning the country dummies likely would lead to biased parameter estimates for the covariates. Indeed, it turns out that treating third-country tax variables as exogenous would be harmful, given the chosen specification. This points to strategic interaction in tax parameters among governments as hypothesized. Moreover, the incremental explanatory power of the identifying instruments for the third-country averages of the taxation variables is relatively high.[13] The latter renders the insignificant over-identification tests meaningful. Overall, we may conclude that the IV-2SLS models work well.

Regarding the covariates determining the Nash equilibrium in tax parameters, we find that larger countries tend to set insignificantly higher statutory tax rates but significantly lower depreciation allowances. Higher production costs are associated with significantly lower statutory rates but significantly higher depreciation allowances. Higher trade costs lead to significantly higher statutory tax rates but insignificantly lower depreciation allowances. Of the six point estimates for the covariates (i.e., the determinants of the Nash tax rates), only two contradict the theoretical hypotheses (namely the effects of country size and costs on depreciation allowances).[14] There is support across the board for the determinants of statutory corporate profit tax rates.

The parameters determining the slope of the reaction function in the two dimensions are highly significant throughout. In particular, they indicate that domestic and foreign statutory tax rates are strategic complements, while domestic statutory tax rates and foreign depreciation allowances are strategic substitutes. In contrast, domestic and foreign depreciation allowances are strategic substitutes while domestic depreciation allowances and foreign statutory tax rates are strategic complements. Hence, all the slope parameters of the reaction function are consistent with the above theoretical model.

However, interdependence across economies is quite complicated in that model. Therefore, it is useful to study its mechanics in terms of policy scenario simulations. We will do so by simulating the effects of hypothetical harmonization scenarios: in one of them, we will study the impact of a simultaneous reduction of statutory tax rates by one percentage point in all countries in the sample; then, we will illustrate the impact of a simultaneous reduction in

[13] In matrix notation, we use $\mathbf{WX}$, $\mathbf{W}^2\mathbf{X}$, and $\mathbf{W}^3\mathbf{X}$ as instruments.

[14] Half of the statistically significant parameters of the covariates are in line with the model predictions.

depreciation allowances by one percentage point; and, finally, we will analyze the consequences of a hypothetical harmonization of the two tax parameters in the European Union (EU) on outsider countries. However, it is useful to illustrate the robustness of our findings before turning to the simulation.

6.5 Sensitivity analysis

We assess the sensitivity of our findings in qualitative terms along two general lines: measurement of some of the right-hand-side variables and the aggregation concept for construction of foreign tax instruments (i.e., the spatial weighting scheme). With respect to the former we pay particular attention to country size, production costs, and trade costs.

In the benchmark models summarized in Table 4, we used log real GDP as a measure of country size. In the theoretical model, we referred to country size as the number of households/workers in the economy. While log GDP might generally be a better measure for aggregate demand, log population size would be closer to our model. However, replacing log GDP by log population size has little influence on the reaction function parameters. This becomes obvious from the set of parameters in the upper block of results reported in Table 3.

−− Table 4 −−

Furthermore, we used GDP per capita as a measure of production costs in the benchmark models. Again there are pros and cons for this choice. The fact that expenditures to cover fixed costs will be accounted for in GDP is among the latter. An alternative measure of production costs would be labor compensation (available from the World Development Indicators 2005). Yet, replacing log GDP per capita by labor compensation renders the results qualitatively unaffected, again (see the second block of results in Table 5).

−− Table 5 −−

The trade cost index in the benchmark models relies on a survey among managers and CEOs. Managers might find it difficult to distinguish between sheer trade frictions and obstacles to market transactions as such. Accordingly, the index might reflect other barriers than just trade barriers. We address this concern by using the average cost-insurance-freight to free-on-board bilateral trade values by country (across all importers) and year in logs. Again, the signs of the reaction function parameters are unaffected by this choice (see the third block of results in Table 5).

With regard to the weights to aggregate foreign economies' tax parameters, the sensitivity of the results with respect to usage of inverse distance-based weights might be a concern. We suggest sensitivity checks along two general lines to infer this issue, namely using alternative weighting concepts such as contiguity weighting (direct neighbors matter with the same weight for tax competition while non-neighbors do not mater at all), trade weighting (there, tax competition is hypothesized to be tougher among natural trade partners), and foreign direct investment weighting (there, tax competition is hypothesized to be tougher among natural foreign direct investment partners). The Appendix provides more detail on the construction of these alternative weighting schemes. The three blocks at the bottom of the table indicate that common borders, higher natural levels of bilateral international trade flows, or higher natural levels of bilateral foreign direct investment are related to tax competition similar to inverse geographical distances. In qualitative terms, the results for the signs of the slope parameters of the reaction function are unaffected by these alternative choices of the weighting scheme. Therefore, we will shed light on quantitative issues with profit tax competition by using the benchmark estimates from Table 4.

6.6 Quantification of profit tax competition

In progress.

7 Concluding Remarks

This paper ventures theoretically and empirically into analyzing a government's problem of competing for FDI using two tax instruments rather than a single one: a statutory profit tax rate and a depreciation allowance parameter. Theoretically, we explore the reaction function in these two dimensions and we investigate how the Nash equilibrium in the two instruments depends on country size, production costs, and trade costs. A characterization of the reaction function yields two testable hypotheses. First, the domestic statutory tax rate is a strategic complement to the foreign statutory tax rate, and a strategic substitute to the foreign depreciation allowance. Second, the domestic depreciation allowance is a strategic substitute to the foreign statutory tax rate, and a strategic complement to the foreign depreciation allowance.

In the empirical part of the paper, we test these hypotheses among others in a panel data-set of 43 countries over the period 1982-2005. We use the statutory corporate profit tax rate and the depreciation allowance parameter as empirical analogues of the two tax instruments in the theoretical model.

The picture that emerges is that changes in corporate tax systems are consistent with much tougher competition for FDI. This increase in competition, in turn, may have been driven by regional integration.

8 Appendix

8.1 Discussion of Hypotheses 3 to 6

Hypothesis 3

It is straightforward to show that at $s = 0$ and for n sufficiently big:

$$\frac{\partial t^*}{\partial s} = \frac{1}{2}(1-c)^{-1}(n+1)^{-3}(2n+1)^{-1}\left(2n^2-3n+2n^3-4\right)(n+2) > 0,$$
$$\frac{\partial \tau^*}{\partial s} = \frac{1}{2}(1-c)^{-1}(n+1)^{-3}(n+2)^{-2}(2n+1)^2\left(n^2-2n-2\right) > 0,$$
$$\frac{\partial d^*}{\partial s} = (-2)\left(4n+3n^2-1\right)^{-2}(n+1)^{-1}c^{-1}\left(2n^2-3n+2n^3-4\right)(2n+1)\,n < 0,$$
$$\frac{\partial \delta^*}{\partial s} = (-2)\left(8n+5n^2+5\right)^{-2}(n+1)^{-1}c^{-1}(n+2)^2\left(n^2-2n-2\right)(2n+1) < 0.$$

Figures 2 and 3 illustrate the results of our simulations concerning the signs of $\frac{\partial t^*}{\partial s}$ and $\frac{\partial \tau^*}{\partial s}$, respectively. In Figure 2 the lower curve represents the values of s and n for which $\frac{\partial t^*}{\partial s} = 0$, assuming that $c = 0.1$. For values above (below) this cruve we have $\frac{\partial t^*}{\partial s} > (<)0$.

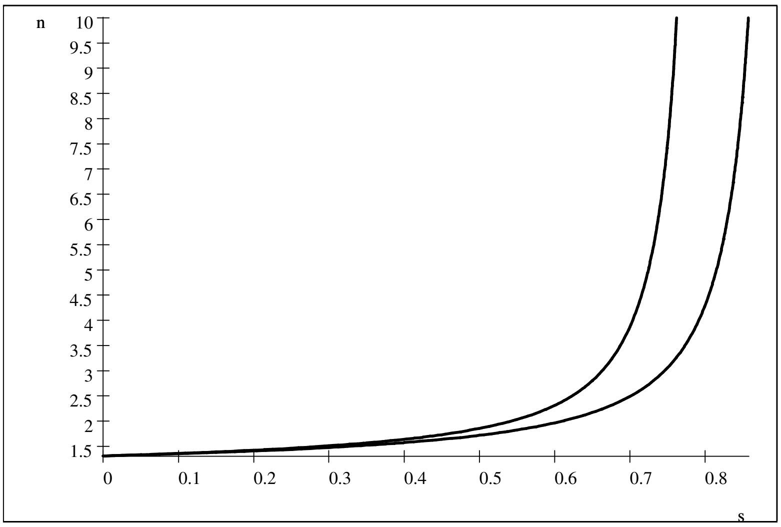

Figure 2: $\frac{\partial t^*}{\partial s} = 0$ for $c = 0.1$ and $c = 0.2$

Raising the marginal cost shifts the ($\frac{\partial t^*}{\partial s} = 0$)-curve upwards, as can be seen from the position of the upper curve, which represents the case of $c = 0.2$. Figure 3 has the equivalent interpretation for $\frac{\partial \tau^*}{\partial s}$.

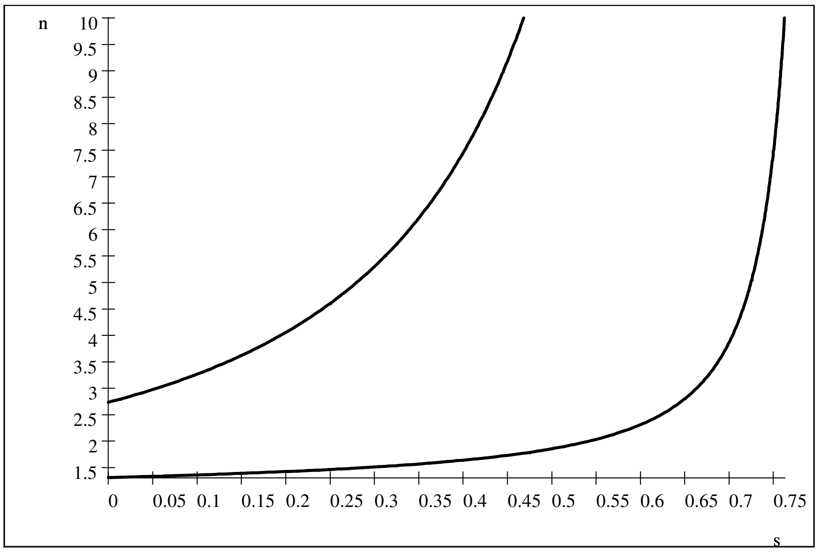

Figure 3: $\frac{\partial \tau^*}{\partial s} = 0$ for $c = 0.1$ and $c = 0.2$

Since a^* and α^* do not depend on s, and d^* and δ^* are negatively related to the respective equilibrium tax rates, it has to be the case that $\frac{\partial d^*}{\partial s}$ and $\frac{\partial \delta^*}{\partial s}$ take on the opposite sign of $\frac{\partial t^*}{\partial s}$ and $\frac{\partial \tau^*}{\partial s}$, respectively, in the parameter regions identified in Figures 2 and 3.

Hypothesis 4

At $s = 0$ we obtain

$$\frac{\partial(t^* - \tau^*)}{\partial s} = \frac{(58n + 39n^2 + 6n^3 + 2n^4 + 30)(n-1)}{2(1-c)(n+1)^2(n+2)^2(2n+1)} > 0,$$

$$\frac{\partial(d^* - \delta^*)}{\partial s} = \frac{(-2)(148n + 429n^2 + 492n^3 + 350n^4 + 168n^5 + 41n^6 - 8)(2n+1)(n-1)}{(8n + 5n^2 + 5)^2(4n + 3n^2 - 1)^2 c} < 0.$$

Hypothesis 5

At $s = 0$ and assuming that n is sufficiently big, we obtain the following signs for the derivates:

$$\frac{\partial t^*}{\partial n} = \frac{1}{2}(2n+1)^{-2}(n+1)^{-2}\left(10n+n^2+7\right) > 0,$$
$$\frac{\partial \tau^*}{\partial n} = \left(-\frac{1}{2}\right)(n+2)^{-3}(n+1)^{-2}\left(3n+6n^2+5n^3+4\right) < 0,$$
$$\frac{\partial d^*}{\partial n} = (-2)\left(4n+3n^2-1\right)^{-2}(n+2)^{-2}c^{-1}(c-1)\left(2n^4-11n^2-2n^3-4n-3\right) > 0,$$
$$\frac{\partial \delta^*}{\partial n} = (-2)\left(8n+5n^2+5\right)^{-2}c^{-1}(1-c)\left(10n+n^2+7\right) < 0.$$

Simulations for the partial derivatives with respect to n indicate that $\frac{\partial t^*}{\partial n} > 0$ and $\frac{\partial \tau^*}{\partial n} < 0$ for a wide range of parameters. In fact for $n \leq 10$ and a wide range of marginal costs these signs hold for the entire range of non-prohibitive trade costs. The same holds true for $\frac{\partial \delta^*}{\partial n} < 0$.

In Figure 4 we present simulations for $\frac{\partial d^*}{\partial n}$. As in Figures 2 and 3 the lower and the upper curves represent values of s and n for which $\frac{\partial d^*}{\partial n} = 0$ given marginal costs of $c = 0.1$ and $c = 0.2$, respectively. We find that $\frac{\partial d^*}{\partial n} > 0$ above the curves.

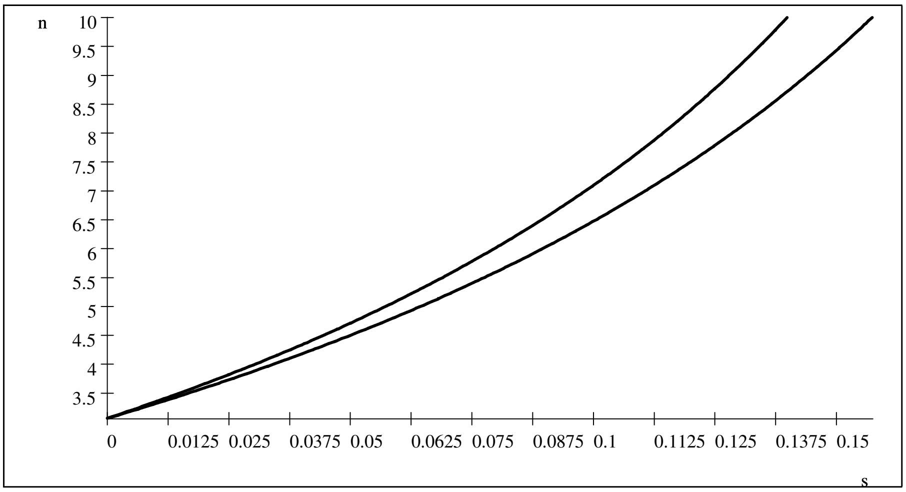

Figure 4: $\frac{\partial d^*}{\partial n} = 0$ for $c = 0.1$ and $c = 0.2$

The simulations thus confirm the results we obtained for the partial derivatives when evaluated at free trade.

Hypothesis 6

For $s = 0$ and n sufficiently big, we obtain $\frac{\partial t^*}{\partial c} = 0$, $\frac{\partial \tau^*}{\partial c} = 0$, and

$$\begin{aligned}\frac{\partial d^*}{\partial c} &= -\left(3n^2+4n-1\right)^{-1}(n+2)^{-1}c^{-2}\left(2n+n^2+3\right)n < 0 \\ \frac{\partial \delta^*}{\partial c} &= -\left(8n+5n^2+5\right)^{-1}c^{-2}\left(2n+n^2+3\right) < 0.\end{aligned}$$

For $n = 1$ (symmetric countries) and $s > 0$, we find that

$$\frac{\partial t^*}{\partial c} = \frac{(-6)\left(32(1-c)^2-9s^2\right)s}{\left(24cs-24s-64c+32c^2+9s^2+32\right)^2} < 0 \text{ for } s \text{ close to zero,}$$

and

$$\frac{\partial d^*}{\partial c} = \left(-\frac{1}{3}\right)\frac{K}{(8-8c-3s)^2(4-4c-3s)^2c^2} < 0,$$

for s can c small enough, where

$$\begin{aligned}K &= 3840cs-1536s-4096c+6144c^2-4096c^3+1024c^4+1008s^2 \\ &\quad -432s^3+81s^4-2016cs^2-2304c^2s+648cs^3-768c^3s+768c^4s \\ &\quad +1008c^2s^2-216c^2s^3+1024\end{aligned}$$

We can also modify the model by letting marginal costs differ across countries and then evaluate how a change in one country's cost affects the equilibrium policies. By assuming that the countries have identical market size ($n = 1$), but that the marginal cost is (weakly) lower in country A than in B, the derivation of the equilibrium policies is very similar to the case of asymmetric countries. In particular, the multinational still locates in A in equilibrium. Let c_i be the marginal cost of the firm when it produces in country $i = A, B$. Simulations then show that, for $c_A \leq c_B$, $\frac{\partial t^*}{\partial c_A} < 0$ and $\frac{\partial d^*}{\partial c_A} < 0$.

8.2 "Natural" Trade- and FDI-based Weights Matrices

As indicated in Section 6.5, in two sensitivity checks we use 'natural' trade and, alternatively, 'natural' foreign direct investment as weights instead of inverse distance. They are derived from cross-sectional empirical models using log bilateral exports and stocks of outward foreign direct investment, respectively, as the dependent variable. Apart from exporter (parent country) and importer (host country) fixed effects, the models include the following trade cost variables on the right hand side: log bilateral distance and a set of dummy variables such as common official language between exporter and importer, common border, European Economic Area membership, and North American Free Trade Area membership.

Since both trade flows and stocks of foreign direct investment take zero values, we follow Santos Silva and Tenreyro and estimate the equations by a Poisson pseudo-maximum-likelihood routine. The associated model predictions are then used to create row-normalized weighting schemes which are positively associated with 'natural' (i.e., predicted) bilateral trade and foreign direct investment, respectively.

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Figure 1 - Evolution of profit tax instruments in a sample of 43 countries (medians)

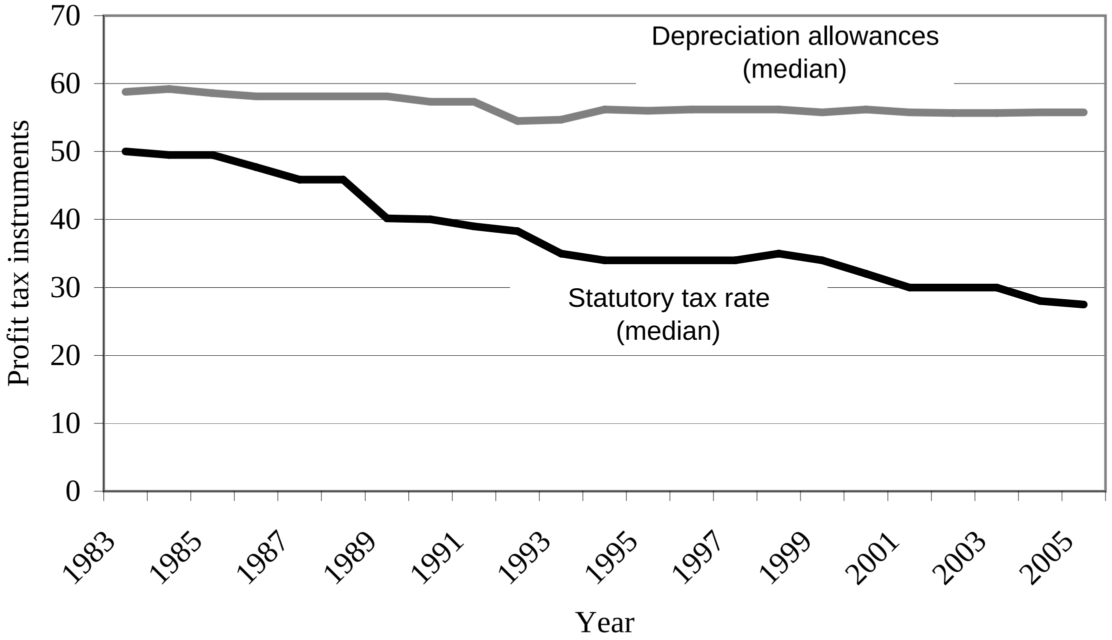

Figure 2 - Evolution of profit tax instruments in a sample of 43 countries (average change)

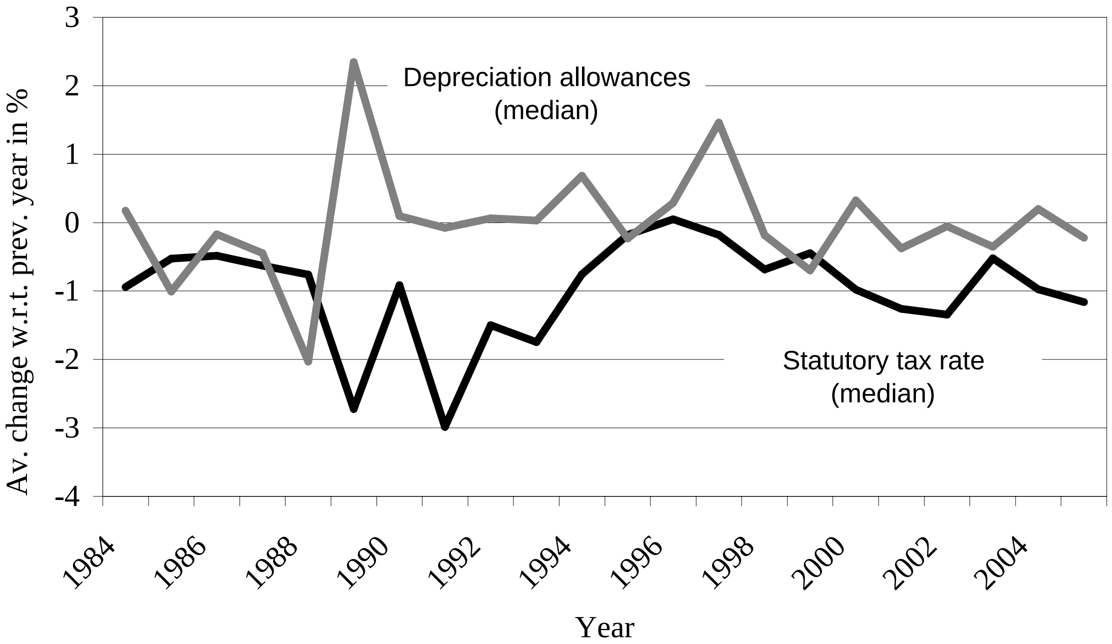

Table 1 - Annual contemporary changes in statutory tax rates and depreciation allowances in 43 countries

		Change in depreciation alowances			
		negative	0	positive	Sum
Change in	negative	14	141	18	173
statutory	0	36	457	31	524
corporate tax rate	positive	2	43	7	52
	Sum	52	641	56	749

Notes: The period is 1982-2000.

Table 2 - Unconditional correlations between domestic and foreign tax instruments

	Domestic tax instruments (dependent variable) in year t					
	Statutory tax rate			Depreciation allowance		
Foreign tax instrument	Coef.	Std.				
Statutory tax rate in year t	2,394	0,208	***	-0,674	0,134	***
Depreciation allowance in year t	-1,522	0,123	***	0,408	0,072	***
Statutory tax rate in year t-2	2,368	0,214	***	-0,601	0,101	***
Depreciation allowance in year t-2	-1,459	0,133	***	0,392	0,056	***
Statutory tax rate in year t-3	2,307	0,220	***	-0,600	0,112	***
Depreciation allowance in year t-3	-1,419	0,139	***	0,406	0,064	***
Statutory tax rate in year t-5	2,155	0,228	***	-0,669	0,116	***
Depreciation allowance in year t-5	-1,406	0,149	***	0,457	0,072	***

Notes: 43 countries over the period 1982-2000. Third-country weights are based on potential (predicted) bilateral goods trade flows. All regressions include country fixed effects but no other covariates. Standard errors are robust to heteroskedasticity and serial correlation. Correlations should not be interpreted as reaction function parameters, since lacking fundamentals lead to inconsistent Nash tax rates.

Table 3 - Reaction function estimation for coporate tax rates and depreciation allowances (potential-trade-based third-country weights)

Explanatory variable		Dependent variable is: Domestic statutory tax rate					Domestic depreciation allowances			
		Theory	Coef.	Std.[a)]	Std.[b)]		Theory	Coef.	Std.[a)]	Std.[b)]
Foreign statutory tax rate	(1)	+	0,150	0,111	0,090	*	-	-0,658	0,221	0,066
Foreign depreciation allowance	(2)	-	-0,552	0,159	0,145	***	+	0,259	0,138	0,049
Country size (log GDP)	(3)	+	0,113	0,034	0,025	***	+	0,113	0,045	0,029
Costs (log GDP-per-capita)	(4)	-	-0,436	0,093	0,093	***	-	-0,281	0,129	0,074
Trade costs (log index value)	(5)	+	0,501	0,052	0,040	***	-	0,027	0,067	0,024
Observations			749					749		
Countries			43					43		
Estimation method			IV-2SLS					IV-2SLS		
Instrumentation:										
Shea's partial R^2 for identifying instruments to explain (1)			0,783					0,872		
Shea's partial R^2 for identifying instruments to explain (2)			0,874					0,927		
Over-identification (p-value of Sargan's χ^2-statistic)			0,187					0,169		
Exogeneity of (1) and (2) (p-value of Hausman-Wu-test)			0,000					0,000		
Fixed country effects (p-value of F-test)			0,000					0,000		

Notes: *** significant at 1%; * significant at 10%. - a) Newey-West-type standard errors which are robust to heteroskedasticity and autocorrelation. - b) Driscoll and K type standard errors which are robust to serial and spatial autocorrelation.

Table 4 - Reaction function estimation for coporate tax rates and depreciation allowances (inverse-distance-based third-country weights)

Explanatory variable		Dependent variable is: Domestic statutory tax rate				Domestic depreciation allowances			
		Theory	Coef.	Std.[a)]	Std.[b)]	Theory	Coef.	Std.[a)]	Std.[b)]
Foreign statutory tax rate	(1)	+	0,246	0,166	0,134 *	-	-0,438	0,128	0,157 ***
Foreign depreciation allowance	(2)	-	-0,439	0,119	0,099 ***	+	0,311	0,088	0,105 ***
Country size (log GDP)	(3)	+	0,100	0,037	0,027 ***	+	0,194	0,050	0,035 ***
Costs (log GDP-per-capita)	(4)	-	-0,411	0,130	0,123 ***	-	-0,851	0,223	0,161 ***
Trade costs (log index value)	(5)	+	0,188	0,051	0,048 ***	-	-0,075	0,037	0,062
Observations			749				749		
Countries			43				43		
Estimation method			IV-2SLS				IV-2SLS		
Instrumentation:									
Shea's partial R^2 for identifying instruments to explain (1)			0,408				0,669		
Shea's partial R^2 for identifying instruments to explain (2)			0,384				0,592		
Over-identification (p-value of Sargan's χ^2-statistic)			0,226				0,169		
Exogeneity of (1) and (2) (p-value of Hausman-Wu-test)			0,000				0,000		
Fixed country effects (p-value of F-test)			0,000				0,000		

Notes: *** significant at 1%; * significant at 10%. - a) Newey-West-type standard errors which are robust to heteroskedasticity and autocorrelation. - b) Driscoll and Kraay-type standard errors which are robust to serial and spatial autocorrelation.

Table 5 - Sensitivity analysis

Explanatory variable		Dependent variable is: Domestic statutory tax rate Coef.	Std.[a)]		Domestic depreciation allowances Coef.	Std.[a)]	
		Using population instead of real GDP to measure country size					
Foreign statutory tax rate	(1)	0,188	0,104	*	-0,419	0,136	***
Foreign depreciation allowance	(2)	-0,440	0,101	***	0,260	0,085	***
		Using wages instead of GDP per capita to measure production costs					
Foreign statutory tax rate	(1)	0,080	0,136		-0,422	0,159	***
Foreign depreciation allowance	(2)	-0,373	0,104	***	0,287	0,104	***
		Using log c.i.f./f.o.b. ratios as a measure of trade costs (s)					
Foreign statutory tax rate	(1)	0,317	0,068	***	-0,226	0,063	***
Foreign depreciation allowance	(2)	-0,645	0,077	***	0,187	0,038	***
		Using contiguity weights to aggregate third-country tax parameters					
Foreign statutory tax rate	(1)	0,326	0,121	***	-0,370	0,047	***
Foreign depreciation allowance	(2)	-0,511	0,077	***	0,105	0,027	**
		Using natural FDI weights to aggregate third-country tax parameters					
Foreign statutory tax rate	(1)	0,375	0,094	***	-0,936	0,125	***
Foreign depreciation allowance	(2)	-0,555	0,079	***	0,433	0,049	***

Notes: *** significant at 1%; * significant at 10%. - a) Driscoll and Kraay-type standard errors which are robust to serial and spatial autocorrelation.