Equilibrium Conditions in Corporate Tax Competition and Foreign Direct Investment Flows

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Abstract. We consider an environment in which a collection of countries attempt to maximize their corporate tax revenue, the latter being viewed as a function of Foreign Direct Investment (FDI) inflow and effective average tax rate which each country-agent sets for itself. Each agent's decisions are 'coupled' to those of others assuming that tax differentials directly affect the flow of FDI; thus, agents essentially compete for FDI. This gives rise to a non-cooperative game, in which each agent takes its turn altering its tax rates, using a differential equation-based model to predict the effect of tax rate changes on its share of FDI. The model combines cross-country FDI flows, tax-rate differentials and other lumped factors to arrive at a steady-state FDI value for each agent, given everyone's corporate tax rates. We explore this game's equilibrium, and in particular the question of whether equilibrium necessarily implies a 'race to the bottom', with near zero corporate tax rates for all players.

Keywords: Tax competition, FDI, corporate tax rates
JEL classification codes: H21,H25,F21,H87

1. Introduction

The liberalization of capital flows during last decade, followed the elimination of trade barriers in the world economy, has made corporate profit taxation and FDI predominant factors in a kind of tax competition game, where a country may attempt to make itself more attractive to capital by lowering its tax rates. Multinational firms (MNF) subsequently transfer prices and benefit themselves from intra-firm debt and profit shifting to countries with lower profit taxes. There is, however, empirical evidence that attributes this behavior to additional important factors, including agglomeration forces, public good provision, market potential, infrastructure, and labour costs. Under the assumption of perfect capital mobility, capital will be continuously shifted between sectors and countries in the world economy until the marginal productivity in each sector became equal to world return. Hence, tax differentials among countries could distort the optimal global allocation of resources and, consequently, international trade.

The belief that tax differentials affect heavily the allocation of international capital flows has two categories of followers. The first claims that countries should coordinate their actions to reach a common corporate tax basis. On the other hand, the supporters of open market rules claim that, in an open market, tax differentials will move to the optimal (for the market) levels, and thus countries' corporate tax rates will converge downwards. In terms of EU tax regulation actions, corporate tax coordination in EU have been largely debated during the last decades; attempts at regulation include the Ruding Report (1992), the Code of Conduct for business taxation (European Communities,1998) and formula apportionment (European Commission, 2001). The last two actions deviate significantly from the Ruding Report (1992) which proposed a minimum EU-wide corporate tax rate of 30%, and clearly departs from company tax rates harmonization in a consolidated company tax base. Recently, there has been some scepticism concerning the efficiency of the Code of Conduct and formula apportionment. For example, Eggert and Haufler (2006) claim that tax avoidance opportunities may even be increased in the new EU low-tax members as a result, and predict that the corporate tax rate harmonization need in EU will soon reappear.

This work extends the literature on corporate tax differentials and FDI with an eye towards corporate tax competition and computational Nash-style games. We propose a non-cooperative FDI distribution game, in which each country competes against the rest in an effort to maximize its corporate tax revenue. The latter quantity depends endogenously on the country's EATR and on the FDI inward flow it is able to attract relative to the others. Of course, corporate tax revenue is not the sole determinant of tax policy, but we will use this assumption as a starting point in this work. The game's equilibrium corresponds to the optimal EATR and FDI inflow levels for the group in a particular year. After calibrating our model, we use it to investigate a series of alternative FDI flow and tax differential scenarios for a group of 12 OECD countries. What we observe is that ultimately, this tax competition game does not lead to a zero (or very low) corporate tax rate equilibrium for the whole group**.** Unlike the majority of the existing literature, here we focus on the problem of raising tax revenue by manipulating corporate tax policy in order to attract FDI.

The remainder of the paper is organized as follows. The next section reviews the literature on tax competition and FDI. Section 3 presents a computational model for corporate tax competition and the game equilibrium conditions with FDI distribution. Section 4 discusses model calibration and the specification of the objective functions based on which countries will act during the game. Section 5 considers equilibrium scenarios for various FDI inflow levels, and contains an empirical analysis of the results. Section 6 summarizes our results, and includes some policy implications and possible future work.

2. Literature review

According to Griffith and Klemm (2004) the tax competition literature can be broken down to so-called direct and indirect studies. The first are based on the examination of the responsiveness of investment incentives to tax rates. Recent indicative studies in this group are those by Hines (1999) and Mooij and Ederveen (2001), which conclude that foreign capital is very sensitive to taxation[1]. It is difficult to extract any policy implications from these studies however; moreover, there is only a vague reference to the ongoing process of tax competition. Representative indirect studies include those of Devereux, Lockwood and Redoano (2001), Devereux, Griffith and Klemm (2002) and, Haufler and Schjelderup (2002). Those attempt to estimate whether one jurisdiction's tax rate reacts to a change in the tax rate in another jurisdiction and they conclude that an interdependence tax rates exists, with ambiguous conclusions about the driving process.

The idea of international capital tax competition was the first in the field of tax competition to be investigated theoretically, primarily from Tiebout (1956) and Oates (1972) and later from Zodrow and Mieszkowski (1986), Gordon (1986) and Wildasin (1988). The basic model for the tax competition literature was the standard model of Zodrow and Mieskowsky (1986) which investigated the effects of capital mobility on capital income taxation in a quite restrictive framework. New contributions thereafter are based on the relaxation of restrictive assumptions of the basic model and the examination of additional aspects of capital mobility, such as governments being either Leviathan or Benevolent, agglomeration economy, differential economic rents across countries, etc.

As far as the field of corporate tax competition is concerned, the recent analysis of the corporate tax rate competition on investment capital mobility according to Hines (2005), has its roots in the study of Diamond and Mirrless (1971) who concluded that small, open economies should avoid taxation of income earned by foreign investors as an incentive to attract international investment capital. Other studies relevant to this work have examined the relation of FDI to corporate tax rates and corporate tax revenues. There is little dispute that the rapid growth of FDI during the last years has led to a subsequent use of tax differentials as a tool for attracting FDI. The apparent correlation of FDI to taxation effects has been investigated from two broad viewpoints in literature, primarily regarding the U.S. One is concerned with the time series estimation of the correlation between level of FDI to annual variation of after-tax rate of return in studies such as Hartman (1984), Boskin and Gale (1987), Young (1988), Slemrod (1990) and Swenson (1994). The other includes Grubert and Mutti (1991), Hines and Rice (1994), Desai,

[1] Mooij and Ederveen (2001) reach this conclusion via meta-analysis.

Foley and Hines (2004a), and Altshuler and Grubert (2004), which explore the location of FDI based on cross-sectional estimations.

The common practice of Multinational Firms (MNF) to use debt to finance foreign affiliates in high tax countries and to use equity to finance on the affiliates in low-tax countries, in other words to accumulate income in low tax rate countries and tax deductions in high tax rate countries is also described in the work of Desai, Foley and Hines (2004) who report that affiliates belonging to the same American parent companies tend to adjust their debt levels lower or higher according to the corporate tax rates of the host countries.

With respect to corporate taxation and FDI flows, we would like to highlight the study of Slemrod (1990), who criticises previous studies like Hartman's (1984) and marks a point of departure for subsequent works. Those first built on the idea of pooled bilateral FDI flows data and aggregate time series data, and also examined the use of an alternative measure for the tax rate, namely the Effective Marginal Tax Rate (EMTR) proposed by Auerbach and Hines (1988). Thereafter, Cassou (1997), explored bilateral FDI flows for individual countries for the period 1970-1989 and found mostly insignificant results of the tax effects on FDI. Other pooled bilateral FDI flows studies are these of Jun (1994), and Devereux and Freeman (1995), which examined a group of OECD countries, also finding statistically non-significant results. Pain and Young (1996), focused on FDI flows from Germany and the UK into 11 countries for the period 1977-1992, and found significant negative elasticities for the UK but non-significant for Germany. Bénassy-Quéré et al. (2005), using a panel of bilateral FDI Flows among 11 OECD countries investigated further agglomeration-related factors, with non-linearities in the impact of tax differentials on FDI location. Finally, Razin and Sadka (2006), in their study of Bilateral FDI inflows in a two–country tax competition model with asymmetric Nash equilibrium noted the importance of tax differentials in determining the direction and magnitude of FDI flows.

Regarding the effect of corporate tax rates on tax revenues and related policy settings by local governments, one could say that tax revenues are influenced by a wide set of factors apart from corporate tax rates[2]. Within that framework, Slemrod (2004) referred to corporate taxes as the "backstop" for the individual income tax. Also, Mutti (2003) concludes that small countries and countries with higher initial statutory tax rates is more likely to proceed to greater statutory tax rate reductions compared to other countries. Specifically, the study undertaken by Becker and Fuest (2007) goes beyond the scope of the standard tax competition models and stresses the perspective of the quality of FDI flows, and the view that corporate taxes distort not only the quantity of FDI flows (and tax revenues) but their quality as well. Thus, in addition to the practice of investment capitals to shift their profits to lower taxed locations, there is a second reason for the elimination of tax revenues, having to do with the quality of FDI inflows and real economic effects. Lately, Clausing (2007), studied the variation among OECD countries in the size of corporate income tax revenues relative to GDP for the period 1979-2002, and found a parabolic relationship between corporate tax rates and corporate income tax revenues, implying a revenue–maximizing corporate income tax rate. The parabolic relationship between tax revenues and tax rates was steeper for countries with higher stocks of FDI relative to their GDP.

3. A Computational Model for Tax Competition

This section describes a non-cooperative tax policy game, including a differential equation-based model for FDI inflow allocation. The central idea is that countries engage in this game by seeking to optimize their corporate tax revenues. They may do so by altering their EATR in an attempt to attract higher FDI inward flows. Of course, any change in the EATR of one country may lead others to also alter their policies. We begin by discussing the mechanics of our model.

[2] Some of these factors are; tax base breadth, tax avoidance, aggressiveness of tax planners, enforcement power by tax authorities .

3.1. An equilibrium model for FDI inflow distribution

Our model for tax competition can be viewed as a non-cooperative game. We consider a collection of players (countries), $i = 1,..., N$, each being interested in maximizing an objective function J_i . Here we will assume that J_i corresponds to the *i*-th player's corporate tax revenue, which we will take to be a function of the corresponding country's effective average tax rate (EATR), u_i , and FDI inflow f_i . Each player, i , acts selfishly, and is thus faced with the problem of choosing u_i to maximize $J_i(u_i, f_i)$. Of course, the FDI inflow, f_i , the player will receive depends on the tax rates set by all other agents, because FDI inflows are affected by tax differentials between countries.

In order to be able to solve the optimization problem facing each player, we must specify how each economy's share of FDI inflow depends on the tax differentials, among other factors, between that economy and its competitors. Towards that end, we consider a probabilistic model in which a fixed amount of FDI inflow stock is to be distributed among the N agents. Specifically, for a given time period (e.g., a particular year), each unit of FDI inflow will have a probability x_i to locate itself in country i . For example, the probability will be higher if a country has low EATR relative to others, if its infrastructure is more developed, if its bureaucracy is simpler, etc. One way of capturing such behavior is to imagine that the probabilities x_i are allowed to change before any FDI is "committed", and that the rate at which they change is

$$dx_i/dt = a_{ij} x_j .$$

The term a_{ij} can be viewed as the rate at which the probability of player i receiving a unit of FDI flows to player j , and will be taken to be of the form:

$$a_{ij} = ke^{c_1(u_i - u_j) + c_2(u_i - u_j)^2 + b_i - b_j}, i \neq j, i, j = 1,..., N . \quad (1)$$

Here, k, c_1, c_2 are constants, and b_i is a lumped index associated with each country that captures the effects of factors other than tax rate differentials, including those mentioned in above. Equation (1) is an exponentiated form of the model of Bénassy-Quéré et al. (2005). Given (1), there is a differential equation that describes how FDI will be expected to be distributed, once economies have decided on their tax rates, namely

$$\frac{dx}{dt} = Ax \quad (2)$$

where $x = [x_1,..., x_N]^T$, and A is the matrix whose *(i,j)-th* element is $[A]_{ij} = a_{ij}$ for $i \neq j$, $[A]_{ii} = -\sum_{j=1, i\neq j}^{N} a_j i$. As defined, the matrix A is a so-called intensity matrix, with all of its off-diagonal elements positive, and column-sums equal to zero, so that Eq. (2) preserves probability (the elements of x remain positive, with a constant sum). It is well-known that A has a single zero eigenvalue, with all other eigenvalues having negative real parts. As a result, Eq. (2) will have a unique equilibrium for x in the space of probability vectors. Specifically, the solution of (2), starting from any initial condition, will converge to the probability vector parallel to the eigenvector of A corresponding to the eigenvalue at zero. We will denote this equilibrium state by $\bar{x}$; $F \cdot \bar{x}$ would then correspond to the expected FDI inflow levels that players would receive, if their EATRs were equal to the elements of the vector u .

We must clarify that Eqs. (1)-(2) are not meant to capture cross-country migration of investment; rather, they are a model for how FDI inflow "decides"' how to distribute itself among the players. Also, in the present context, we will only be interested in the equilibrium of Eq. (2), even though its complete solution, $x(t)$ is a function of time. The notion of time in Eq. (2) does not have any physical significance in the context of our tax competition game.

3.2 The Tax Competition Game

Let F be the sum total of FDI inflow for which the players compete. Given their objective functions J_i, and initial values for their tax rates u_i, for $i = 1,...,N$, the players engage in the following game:

1. Repeat
2. For each player, $i = 1,...,N$,
3. Given all players' tax rates, u, determine A and compute the steady-state probabilities, $\bar{x}$, of each player receiving one FDI unit, from (2), using any initial condition for x.
4. Compute the FDI levels each player is expected to receive, as $f_i = F \cdot \bar{x}_i$, $i = 1,...,N$.
5. Find the tax rate u_i that maximizes $J_i(u_i, f_i)$, treating f_i as fixed.
6. End For
7. Until all agent's tax rates do not change compared to the last iteration (within some specified tolerance).

We note that in the above algorithm, players take turns adjusting their tax rates until equilibrium is reached. This turn-based process is “artificial” and is only there due to computational considerations, and the order in which players take their turn is unimportant. One could just as easily describe the game as an optimization problem where all players act simultaneously. In either case, players have full information as to their competitors' choices.

4. Model Calibration and Computation

We proceed to discuss the specific choice of model parameters and objective functions that will be used when simulating the game described in the previous section.

4.1 Empirical analysis, data and assumptions

In an economy where individual countries compete in terms of corporate taxation trying to maximize their tax revenues, we will consider FDI inward flows[3] and Effective Average Tax Rates (EATR), as being the key factors that affect countries’ policy decisions. In the following, we assume that each country acts according to its own objective function, and alters its EATR using the differential equation–based model (2), in order to better position itself among its peers in terms of tax revenue. Tax revenue will be taken to be a function of EATR and FDI inflow only. To calibrate our model, we obtained FDI inflow, EATR and corporate tax revenue data for a group of 12 OECD countries over the period 1982-2005 (data sources listed in the Appendix). The group included Canada, France, Germany, Greece, Italy, Japan, Netherlands, Portugal, Spain, Sweden, the UK and the US.

We assumed that the response of FDI inflows to tax differentials (and thus the FDI probability flow rate in (1)) follows the nonlinear model of Bénassy-Quéré etal. (2005) (we will elaborate on this in Section 4.3). We did not attempt to account for welfare considerations, investment capital profit maximization criteria, country agglomeration factors, public goods and individual characteristics. Rather, we assume that in the short/middle run these factors change slowly compared to the changes FDI inflow can undergo. In this framework, countries’ individual characteristics (also including infrastructure, bureaucracy, cultural factors, etc.) are to be captured by a country-specific index. In our model, EATR and FDI are the only policy tools, and thus differences in the values of the index between two countries indicate a corresponding difference in FDI inflow levels received, if the two adopt the same EATRs. Finally, our model does not account for the benevolent or leviathan individual countries’ welfare policy or for the MNF profit maximization strategies.

[3] For our purposes, FDI inward flow includes the influx of FDI originating worldwide.

4.2 Objective function specification

We estimated four alternative objective functions and applied misspecification tests to identify the most appropriate one. The four functions are detailed in the Appendix. Here, we relied on the relevant literature and employed EATR and $EATR^2$ in order to account for the generally parabolic nature of the corporate tax revenue curve (e.g., Kimberly Clausing (2007) and Becker and Fuest (2007)). Our models also included the variable FDI inward flow, in order to capture its effect on corporate tax revenues. Testing for the most robust model of corporate tax revenue by employing other possible determinants was outside the scope of this paper; thus, we did not include factors such as income taxation, tax compliance, hidden economy, public goods, and other factors that could hinder the effectiveness of tax measures. To account for the countries' individual characteristics and heterogeneities we preformed individual regressions for each of them, instead of estimating fixed effects from pooled data. We chose to "tailor" the objective function to each country individually, as opposed to working with the data in panel form for two reasons. The first is that countries are assumed to act selfishly in the game, so it makes sense for them to have their own objective function, as opposed to acting according to some "average" criterion. Because tax revenue characteristics vary considerably across the sample, aggregating the data would "homogenize" the players' behaviour and distort the game. The second reason has to do with the use of the Schwarz Information Criterion (SIC, see below) which indicated that the aggregate SIC of individual cross-sections estimation was higher than of a corresponding panel model.All four competing regression models were static.

The four alternative models, numbered 1 through 4, where tested first for stationarity by applying the KPSS (The Kwiatkowski, Phillips, Schmidt, and Shin, 1992) test on all variables. KPSS was selected because it differs from the other unit root tests in that the series are assumed to be (trend-) stationary under the null hypothesis. The KPSS statistic is based on the residuals from the OLS regression of the exogenous variables. The test indicated that there was stationarity for the whole set of variables in models 3 and 4 mostly in trend and intercepts, and in a few cases in intercepts only. In models 1 and 2 that consider corporate tax revenue and FDI as fractions of GDP, we found some non-stationarity and balance problems in some cases. Additional tests performed included the SIC[4], subsequent misspecification tests using corellogram Q stats on residuals, and structural stability Ramsey RESET and CUSUM tests. On the basis of all test performed, model 4 emerged as the most appropriate one, being balanced in terms of stationarity and the properties of its variables.

As we have already mentioned, we endowed each country in the group with its own version of model 4. For comparison, the model of choice was estimated both as a set of 12 individual regressions, as well as a pooled model, and the SIC[5] was applied in order to compare the two approaches. We use the SIC which penalizes over-parameterization more heavily than tests at the conventional significance levels. The model selection criteria were computed as follows:

$$SIC_{pooled} = MLL - 0.5k_{pooled}\log(NT)$$

$$SIC_{individual} = \sum_{i=1}^{12} MLL_i - N[0.5k_i \log(T)]$$

where MLL_{pooled} and MLL_i denote the maximum log likelihoods of the pooled model and the i_{th} country time series regression, respectively; k_{pooled} is the number of parameters estimated in the fixed effects model, (i.e., 15 in our case; the three explanatory variables plus 12 country specific effects) and k_i is the number of parameters estimated in the individual country time series regression, (i.e. four in our case;the number of explanatory variables plus an intercept); N and T denote the number of countries and estimation period, respectively. Because $SIC_{individual}$ is greater[6] than SIC_{pooled} the individual equations model is preferred over the panel model.

[4] The model that maximizes SIC is preferred .
[5] M. Karanassou et al. (2003).
[6] $SIC_{individual}$=385.8 and SIC_{pooled}= 82.96

Table 1: Descriptive Statistics[7] for the period: 1982-2005

	Mean	Median	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Probability	Sum
EATR	0.31	0.30	0.04	0.04	2.24	2.40	0.36	7.36
EATR_Sqared	0.10	0.09	0.03	0.18	2.26	2.44	0.39	2.37
FDI iward flows	0.19	0.11	0.21	1.71	6.24	40.53	0.07	4.52
CORP.TAX REVENUE	0.43	0.44	0.18	0.33	2.72	2.26	0.45	10.35

Notes: Corporate tax revenues and FDI inward flows are in US dollars (x 10^{10}).
For all countries there are 24 annual observations for each variable except Portugal with 16 years data available for Corp. Tax Revenue

Table 2: Equation estimation (Variables coefficients)[8]

	Canada	France	Germany	Greece	Italy	Japan	Netherl.	Portugal	Spain	Sweden	UK	US
Intercept	-10.11*	-2.17*	-1.87	0.25**	0.56	-19.52**	1.53**	-0.27	1.17	0.12	13.26	-2.70
EATR	71.89*	17.68**	12.28*	-1.15*	-3.88	121.82**	-8.24**	2.94	-8.49	-0.24	-97.17	48.63
EATR_SQ	-125.68*	- 32.45**	-17.01*	1.30	9.21	-169.76**	11.38**	-6.59	15.87	0.08	181.23	-119.43
FDI	0.29*	0.46**	-0.01	0.58*	1.74**	-7.36**	0.09**	-0.10	0.68**	0.04	0.21**	0.50**
OBS	24.00	24.00	24.00	24.00	24.00	24.00	24.00	16..00	24.00	24.00	24.00	24.00
Adj.R^2	0.40	0.87	0.32	0.93	0.42	0.42	0.76	0.69	0.47	0.49	0.71	0.51

Note: *Significant at 5%, **Significant at 1%.
The above coefficients (model 4) are used for the countries' individual corporate tax revenues objective functions.

It is important to emphasize that, before estimating each equation and applying misspecification tests, we verified that all four models yielded the same "trend" in the numerical experiments described later (for example, they largely agreed on which countries tend not to follow others to very low tax rates[9]) . This suggests that in equilibrium, tax competition model is not sensitive to the changes of objective function coefficients as these were calculated by the different regression models. In other words, the results appear to be robust within the set of coefficients selected.

4.3 Calibrating the FDI equilibrium equation

To calibrate the basic FDI inflow distribution model (2), we obtained tax revenue, EATR and FDI inflow data for countries in our sample, for the years 1982-2005, excluding years in which some country had a negative FDI inflow (years 1984, 1986, 1988, 1989, 1992, 2004). In particular, we followed the approach used in Bénassy-Quéré et al. (2005) and performed a nonlinear regression with panel data, to relate log-differences in FDI inflow between pairs of countries (when the difference was positive) to tax differentials and cubic tax differentials as follows:

$$\log(FDI_i - FDI_j) = c_1(u_i - u_j) + c_2(u_i - u_j)^3 + c_3, \tag{3}$$

where $i \neq j, \quad i, j = 1,...,N$. The resulting coefficients (to be used in Eq. (1)) and their statistical properties are shown in Table 3.

[7] For Data sources refer to Table A1 in the Appendix.
[8] For the alternative models refer to Table A2 in the Appendix .
[9] An investigation of the determinants of such a behaviour lays beyond the scope of the work but, in line with the literature should be attributed to countries' individual characteristics eg; market openness, accessibility, infrastructures level, agglomeration forces and also the magnitude of the economy in terms of GDP.

Table 3: Coefficients for (3) obtained from N=476 observations

Coefficient	Value	Std. Error	T-statistic	*p*-value
c_1	8.174052	1.686984	4.845364	0.0000
c_2	-174.8769	74.58489	-2.344669	0.0195
c_3	8.515873	0.078750	108.1380	0.0000

After setting the coefficients c_1, c_2 in our FDI flow model (1) as per Table 3, the only unknowns in the equilibrium of Eq. (2) are the players' indices, b_i, which may vary for each year, and which are needed to calculate the intensity matrix A. Using an adaptive procedure, we tuned the b_i so that for each year in the data set, the equilibrium state, $\overline{x}$, matched the observed fraction of FDI inflow stock received by each country. Finally, for each country, we retained the average of its *b*-index over the years in the dataset. Table 4 shows the resulting index averages for each country. We note (and this should be obvious from Eq. 1) that the absolute level of the index is not important as far as FDI distribution is concerned; it is only the differences between countries that determine the "propensity" of FDI to locate to one country versus others. Thus, without loss of generality, we have used zero to be the "reference level", i.e., the lowest *b*-index. This will not affect our results because adding any fixed constant to the exponent in (1) does not alter the steady-state of the differential equation (2). In fact, any constant present in the exponent can be absorbed in the coefficient *k* of (1).

Table 4: *b*- index values for the countries in the dataset (averaged over time).

Country	index (b)
Canada	1.0228
France	1.3930
Germany	0.5923
Greece	0.0408
Italy	0.7358
Japan	0
Netherlands	1.1098
Portugal	0.2200
Spain	1.3358
Sweden	0.9598
UK	1.7898
US	2.0412

When playing the game described in the previous section, we also applied upper and lower bound constraints to the tax rates u, so that no agent could institute either zero or very high tax rates:

$$T_{min} \leq u_i \leq T_{max}, i = 1,..., N. \quad (4)$$

In our simulations, we used $T_{min} = 0.03$ (3%) and $T_{max} = 0.65$ (65%).

4.3 Finding the game's equilibrium

Given the decisions of its competitors, an agent i maximizes its objective when the following first-order condition is satisfied:

$$\frac{\partial J_i}{\partial u_i} + F \frac{\partial J_i}{\partial f_i} \frac{\partial \overline{x}_i}{\partial u_i} = 0, \quad (5)$$

where the last term, $\partial \bar{x}_i / \partial u_i$, can be computed from the FDI distribution model by finding the partial derivatives (with respect to each u_i) of the eigenvector that corresponds to A's zero eigenvalue. To find the game's equilibrium, we applied the algorithm given in the previous Section. Alternatively, one could solve the first-order conditions after modifying (5) to account for the constraints (4) with suitable Lagrange multipliers. Our particular choice of J_i was

$$J_i = \gamma_0 + \gamma_1 u_i + \gamma_2 u_i^2 + \gamma_3 f_i, \qquad (6)$$

where J_i represents tax revenue**.** The values of the coefficients $\gamma_0, \ldots, \gamma_3$ for each country are shown in Table 5 (see also Appendix).

Table 5: Coefficients for the model (6).

Country	γ_0	γ_1	γ_2	γ_3
Canada	-10.11	71.89	-125.68	0.29
France	-2.17	17.68	-32.45	0.46
Germany	-1.87	12.28	-17.01	-0.01
Greece	0.25	-1.15	1.30	0.58
Italy	0.56	-3.88	9.21	1.73
Japan	-19.52	121.82	-169.76	-7.36
Netherlands	1.53	-8.23	11.38	0.09
Portugal	-0.27	2.94	-6.58	-0.10
Spain	1.17	-8.49	15.86	0.68
Sweden	0.12	-0.24	0.08	0.04
UK	13.26	-97.17	181.23	0.21
US	-2.70	48.63	-119.42	0.50

We note that the objective function is nonlinear in u_i. Besides the presence of the squared term, a source of nonlinearity is the relationship between f_i and u_i because u_i influences f_i through the equilibrium state of (2).

5. Results and Discussion

We simulated the game described in Sec. 2.2, where countries were allowed to optimize their tax revenue (5) by adjusting their EATR levels, u_i, competing for a total FDI inflow level equal to that for 2005 ($F = 544533$ mil. USD). When applying the algorithm of Section 3.2, equilibrium was reached typically within two to three turns. Table 6 shows the optimal EATR levels and corresponding fraction of the thtal FDI captured by each country at the game's equilibrium, where no country was better off by unilaterally changing its tax rate. Because total FDI inflows were increasing during 1982-2005 (plots for the countries in our sample are given in the Appendix) we explored alternative scenarios of FDI total inflow values (with the base corresponding to the year 2005). Tables 7-14 show the results of the same numerical experiment, this time with the total FDI inflow set to 0.5, 0.8, 1.2, 1.5, 2, 5, 10, and 20 times the total FDI inflow for 2005.

Table 6: Optimal EATR for players in the FDI distribution game. Players compete for a total FDI level equal to the 2005 total for countries in the sample. We have included the 2005 EATR and FDI amounts for comparison.

Country	2005 EATR	2005 fraction of FDI captured	Optimal EATR at equilibrium	Fraction of FDI captured at equilibrium
Canada	0.2843	0.0531	0.2840	0.0925
France	0.2539	0.1489	0.2610	0.1095
Germany	0.3150	0.0659	0.3620	0.0585
Greece	0.2061	0.0011	0.0300	0.1281
Italy	0.2602	0.0367	0.6500	0.0004
Japan	0.3170	0.0051	0.3950	0.0399
Netherlands	0.2512	0.0761	0.0300	0.1738
Portugal	0.2021	0.0073	0.2300	0.0834
Spain	0.2611	0.0459	0.6500	0.0004
Sweden	0.2089	0.0187	0.0300	0.1665
UK	0.2392	0.3557	0.6500	0.0005
US	0.2904	0.1855	0.2010	0.1465

Table 7: Optimal EATR levels at game equilibrium when players compete for a total FDI level equal to 50% of the 2005 total for countries in the sample.

Country	Optimal EATR at equilibrium	Fraction of FDI captured at equilibrium
Canada	0.2850	0.0923
France	0.2670	0.1078
Germany	0.3610	0.0591
Greece	0.0300	0.1271
Italy	0.6500	0.0004
Japan	0.3770	0.0453
Netherlands	0.0300	0.1725
Portugal	0.2270	0.0836
Spain	0.6500	0.0004
Sweden	0.0300	0.1653
UK	0.6500	0.0005
US	0.2020	0.1457

Table 8: Optimal EATR levels at game equilibrium when players compete for a total FDI level equal to 80% of the 2005 total for countries in the sample.

Country	Optimal EATR at equilibrium	Fraction of FDI captured at equilibrium
Canada	0.2840	0.0925
France	0.2630	0.1089
Germany	0.3610	0.0589
Greece	0.0300	0.1276
Italy	0.6500	0.0004
Japan	0.3880	0.0420
Netherlands	0.0300	0.1732
Portugal	0.2290	0.0835
Spain	0.6500	0.0004
Sweden	0.0300	0.1659
UK	0.6500	0.0005
US	0.2020	0.1461

Table 9: Optimal EATR levels at game equilibrium when players compete for a total FDI level equal to 1.2 times the 2005 total for countries in the sample.

Country	Optimal EATR at equilibrium	Fraction of FDI captured at equilibrium
Canada	0.2840	0.0925
France	0.2590	0.1100
Germany	0.3620	0.0584
Greece	0.0300	0.1286
Italy	0.6500	0.0004
Japan	0.4020	0.0378
Netherlands	0.0300	0.1745
Portugal	0.2320	0.0832
Spain	0.6500	0.0004
Sweden	0.0300	0.1672
UK	0.6500	0.0005
US	0.2010	0.1467

Table 10: Optimal EATR levels at game equilibrium when players compete for a total FDI level equal to 1.5 times the 2005 total for countries in the sample.

Country	Optimal EATR at equilibrium	Fraction of FDI captured at equilibrium
Canada	0.2830	0.0871
France	0.2570	0.1039
Germany	0.3620	0.0535
Greece	0.0300	0.1044
Italy	0.0300	0.1273
Japan	0.4110	0.0309
Netherlands	0.0300	0.1416
Portugal	0.2330	0.0779
Spain	0.6500	0.0003
Sweden	0.0300	0.1357
UK	0.6500	0.0003
US	0.2010	0.1371

Table 11: Optimal EATR levels at game equilibrium when players compete for a total FDI level equal to 2 times the 2005 total for countries in the sample.

Country	Optimal EATR at equilibrium	Fraction of FDI captured at equilibrium
Canada	0.2820	0.0874
France	0.2530	0.1050
Germany	0.3620	0.0533
Greece	0.0300	0.1048
Italy	0.0300	0.1279
Japan	0.4260	0.0266
Netherlands	0.0300	0.1423
Portugal	0.2360	0.0778
Spain	0.6500	0.0003
Sweden	0.0300	0.1363
UK	0.6500	0.0003
US	0.1990	0.1380

Table 12: Optimal EATR levels at game equilibrium when players compete for a total FDI level equal to 5 times the 2005 total for countries in the sample.

Country	Optimal EATR at equilibrium	Fraction of FDI captured at equilibrium
Canada	0.2770	0.0827
France	0.2340	0.1020
Germany	0.3640	0.0473
Greece	0.0300	0.0882
Italy	0.0300	0.1076
Japan	0.4720	0.0121
Netherlands	0.0300	0.1198
Portugal	0.2640	0.0683
Spain	0.0300	0.1278
Sweden	0.0300	0.1147
UK	0.6500	0.0002
US	0.1950	0.1293

Table 13: Optimal EATR levels at game equilibrium when players compete for a total FDI level equal to 10 times the 2005 total for countries in the sample.

Country	Optimal EATR at equilibrium	Fraction of FDI captured at equilibrium
Canada	0.2680	0.0848
France	0.2060	0.1079
Germany	0.3670	0.0447
Greece	0.0300	0.0917
Italy	0.0300	0.1118
Japan	0.5040	0.0064
Netherlands	0.0300	0.1244
Portugal	0.3580	0.0430
Spain	0.0300	0.1327
Sweden	0.0300	0.1192
UK	0.6500	0.0002
US	0.1850	0.1332

Table 14: Optimal EATR levels at game equilibrium when players compete for a total FDI level equal to 20 times the 2005 total for countries in the sample.

Country	Optimal EATR at equilibrium	Fraction of FDI captured at equilibrium
Canada	0.2500	0.0913
France	0.1680	0.1175
Germany	0.3730	0.0411
Greece	0.0300	0.0928
Italy	0.0300	0.1132
Japan	0.5300	0.0032
Netherlands	0.0300	0.1259
Portugal	0.4360	0.0184
Spain	0.0300	0.1343
Sweden	0.0300	0.1207
UK	0.6500	0.0002
US	0.1670	0.1415

By examining the game's equilibrium for various sizes of FDI inflow, it is clear that the players-countries do not all race one another to ever-lower EATRs. We observe that there are three main groups of players that emerge, which we shall name 'A', 'B' and 'C', based on their rate-setting behaviour. Group 'A' includes Germany, Japan, the UK and Portugal. These countries do react to their peers' decisions but do not lower their rates excessively in order to compete. They seem unconcerned about the game and may, for example, attain tax revenues maximization focusing on their own investment capital. Group 'B' contains Greece, the Netherlands and Sweden; these three countries always compete aggressively and adopt the minimum EATR level in order to capture the maximum possible FDI inflow. This behaviour might be explained by the need to overcome the tax benefit bonus offered to international investment capital by the remaining countries of group 'C'. That group, containing Canada, France and the US, generally maintain their 2005 equilibrium position and make only slight reductions in their EATR to compete for FDI inflows as the total FDI inflow increases. Specifically, this group of countries seem to take advantage of the tax bonus they offer as host countries. Overall, it is apparent that even in the scenario of a 20x elevation of FDI inflow there is no EATR "race to bottom" for all because, although 'B'-group countries adopt the minimum level (i.e., 3% in our simulation), those of the other groups maintain their EATR at significantly higher levels.

The equilibrium behavior of players is related to the parabolic nature of their tax revenue curves with respect to EATR (see Table 5). For Canada, France, Germany, Japan, Portugal and the US the curves are concave, while for Greece, Italy, Netherlands, Spain, Sweden and the UK they are convex. We must note that the corporate tax revenue models used here are static, and that we have not attempted to account for other factors that may affect their shape, including economic geography, infrastructure level, GDP magnitude, openness, tax evasion, enforcement power by tax authorities as well as other features characterizing the country's specific political and economical position. Players with convex curves optimize their tax revenue either at very low or very high EATRs. For some, namely Italy and Spain, the decision depends on the amount or FDI inflow they are competing for, so that for low amounts they are better off with the maximum EATR, as countries in group 'A', while for larger inflows it is optimal for them to compete as "strongly" as possible and move to group 'B'. For the remaining countries with convex objective functions matters are such that their maximization point is not altered with increasing FDI inflows, at least for the range of values in our experiments. Finally, we note that Portugal's behavior in the game may have been distorted because of the lack of sufficient data with which its objective function was estimated (in particular, there were eight years of missing tax revenue data for Portugal in the data set for Table 2).

6. Conclusions

We have proposed a game-based model for describing tax competition among countries that seek to maximize coprporate tax revenue by adjusting their corporate tax rates in an effort to attract FDI. Numerical experiments using data from twelve OECD countries during 1982-2005 suggest that there will be no "race to the bottom" for the whole group as a result of tax competition game even for large amounts of FDI inflow. Our results are in line with the recent literature discussing the existence of a tax rent bonus offered by large countries to mobile investment capital (e.g., in the case of USA, the UK, and France), and appear to support the suggestion[10] that FDI flows do not always add to countries' tax revenues (e.g., in the case of Germany and Japan).

Our model suggests that counties starting this game possessing a big stake of the total FDI inflow, and also possessing features like large GDP, openness, high levels of public goods and infrastructure, generally seem reluctant to lower their corporate tax rates. Such countries (categories 'A' and 'C' in our analysis) either exhibit no interest in FDI flows because pursuing them would lower their tax revenues from the outset, or do not need to lower drastically their EATR to attract FDI. On the other hand, countries in group 'B' compete aggressively and reduce their EATR to the lowest possible.

In the case of the EU-25, which follow a strict convergence program with the intention of eventually leading to a unified level of development and similar political and economic characteristics, the scenario of convergence to zero EATR equilibrium levels in an extended time span appears weak. If,

[10] eg Becker and Fuest (2007).

in the ideal situation, these uniform conditions are achieved, they would likely lead to generally uniform *b* indices across the EU-25 countries and will subsequently drive long-run equilibrium to homogenous EATR levels. However, there is no a priori reason that those levels should be low, if for example the *b* indices of countries outside EU-25 are lower than those of the member-states. Even if that is not the case, it is unlikely that the objective functions of countries both inside and outside the EU-25 are "homogenized" in such a way that the game equilibrium occurs at very low EATRs. Finally, it would be risky to conclude from the analysis above that countries like Greece, Netherlands, Sweden and others with similar behaviour in the game, would benefit by first minimizing their EATR, since there are also other important determinants of the total (beyond corporate) tax revenues, e.g., personal income tax rates, indirect taxes and tax avoidance issues that we have not considered here. To extract safer policy implications on tax competition policy one should also take into consideration other determinant factors of tax revenues in total. Additionally, there arise important for the political economy and welfare policy dilemmas that local governments have to take into consideration.

Opportunities for future research include augmenting the FDI distribution model to incorporate dynamic effects in the specification of the intensity matrix *A* and the country-specific indices *b*, differences between investor and host courtiers in double taxation schemes, as well as economic geography gravity variables. It would also be of interest to extend this work to the setting where the countries' decision criterion includes other quantities in addition to corporate tax revenue. Finally, it would be important to investigate the likely consequences of tax avoidance and income shifting from the personal to the corporate tax base in order to account for the amount of corporate tax revenue that can be attributed to it.

Appendix

Table A1: Data Sources

Variables[11]:	**Sources:**
Income Tax Revenues	*OECD Revenue and National Accounts Databases.*
FDI inflows	*United Nations Conference of Trade and Development (UNCTAD) Statistical DataBases.*
EATR and STR	*Institute of Fiscal Studies (IFS) Publications*
GDP	*World Development Indicators Data and Statistics*

Currency in US dollars

Table A2: Alternative Regression Models

Model 1	Model 2	Model 3	Model 4
Corp.Tax Revenues/GDP	Corp.Tax Revenues/GDP	Corp.Tax Revenues	Corp.Tax Revenues
EATR	EATR	EATR	EATR
EATR_Squared	EATR_Squared	EATR_Squared	EATR_Squared
FDIInward Flows/GDP*EATR	FDI Inward Flows/GDP	FDI Inward Flows*EATR	FDI Inward Flows

Note: Corp.Tax Revenues is the dependent variable

FDI data definition: FDI Inward flows (inflows) characteristics[12]

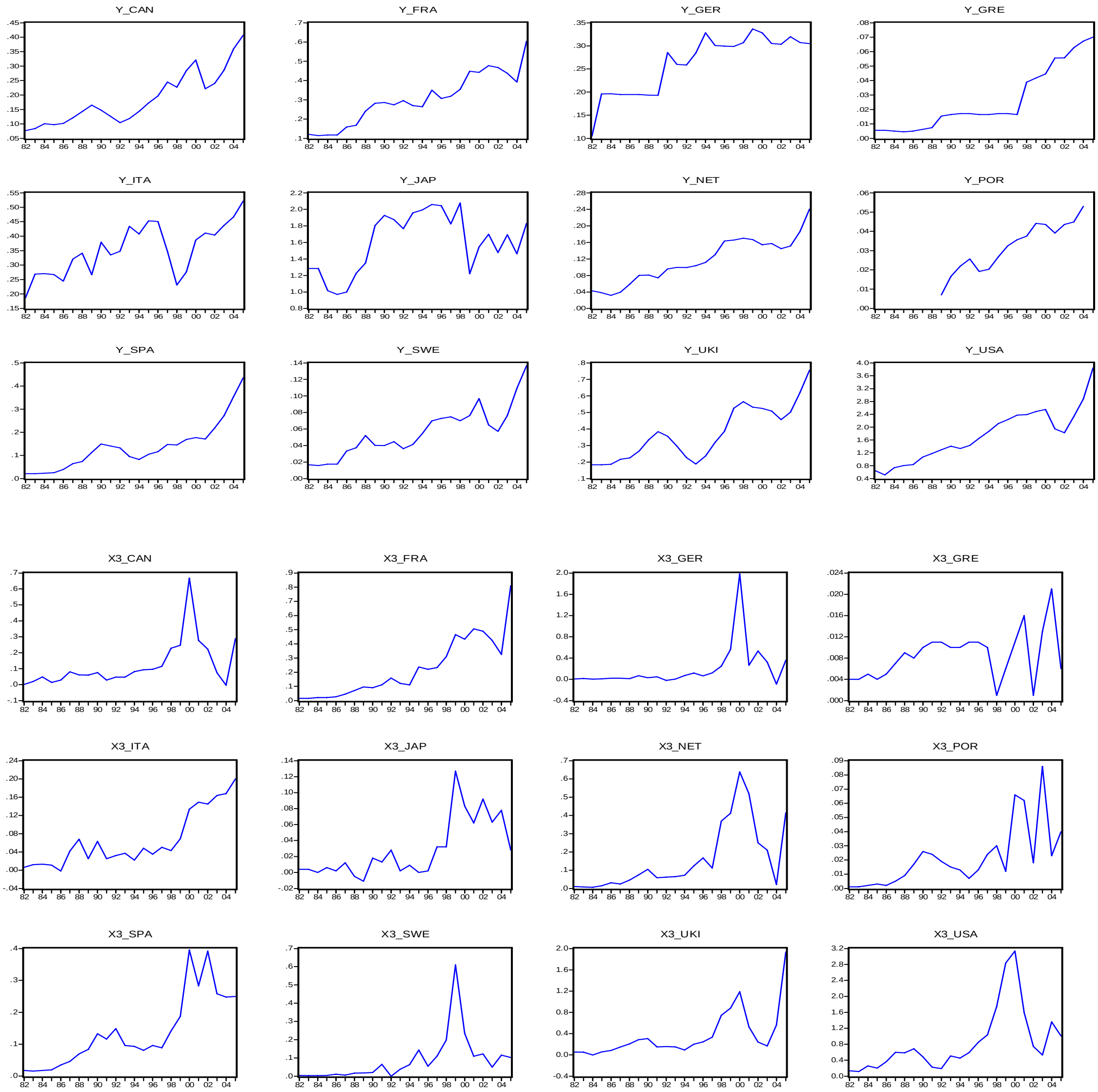
According to the UNTACD Data specification, '*Data on FDI flows are on a net basis (capital transactions´ credits less debits between direct investors and their foreign affiliates). Net decreases in assets (FDI outward) or net increases in liabilities (FDI inward) are recorded as credits (recorded with a positive sign in the balance of payments), while net increases in assets or net decreases in liabilities are recorded as debits (recorded with a negative sign in the balance of payments). Hence, FDI flows with a negative sign indicate that at least one of the three components of FDI (equity capital, reinvested earnings or intra-company loans) is negative and not offset by positive amounts of the remaining components. These are instances of reverse investment or disinvestment*'.

Tax related data definition: EATR and Corporate Tax Revenues

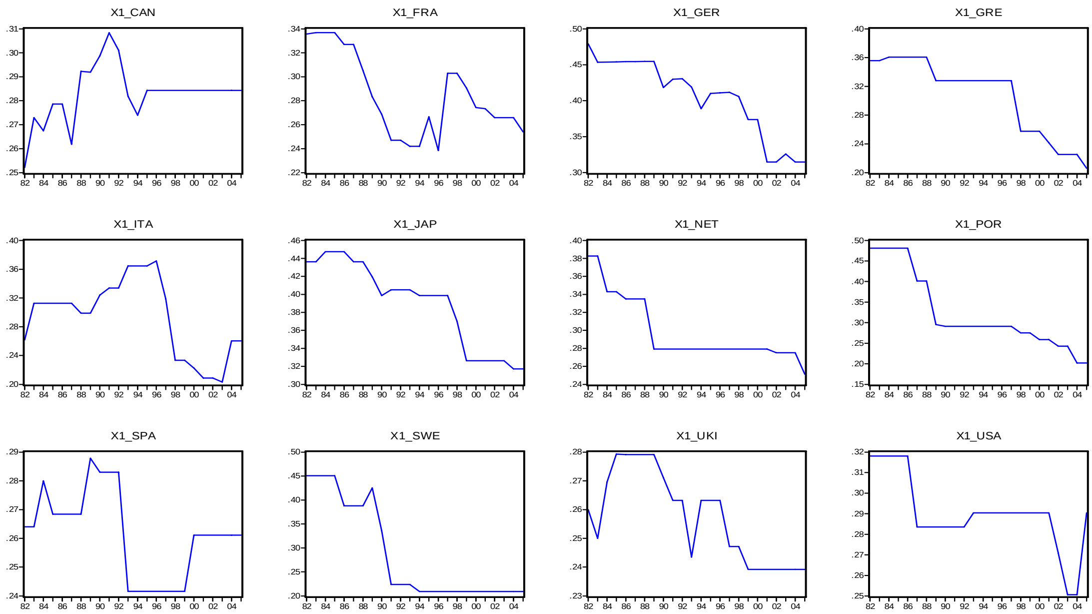
EATR equals a weighted average of an EMTR and an adjusted statutory tax rate. It can therefore be interpreted as summarising the distribution of effective tax rates for an Investment project over a range of profitability. For the calculation of countries EATR[13] the IFS, made specific assumptions e.g. investment in plant and machinery, financed by equity or retained earnings, taxation at shareholder level not included, rate of economic rent: 10% (i.e. financial return 20%), real discount rate: 10%, inflation rate: 3.5%, depreciation rate: 12.25%[14]

[11] For details see Appendices
[12] For details refer to : http://www.unctad.org/Templates/
[13] For definition on the formula applied refer to Devereux and Griffith (2003).
[14] http://www.ifs.org.uk/publications.php?publication_id=3210.

Graph 1: The Objective Function Variables Plot. [15]



[15] The vertical axis indicates tax revenue (x 10^{-10}) for the variable Y; the variable X1 represents EATR; X3 represents FDI inflow (x 10^{-10}). Horizontal axis is in years.



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