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How European Countries (should) react to Capital Income Tax Competition

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Abstract

This paper wants to add two new aspects in the estimation of tax reaction functions for a sample of European countries. First we are using a new set of characteristic variables, which are theoretically based upon the endogenous growth paper by Lejour and Verbon (1997). Second, compared to previous studies, we will use the generalized spatial two stage least squares (GS2SLS) procedure introduced by Kelejian and Prucha (1997) in order to estimate the spatially autoregressive model consistently. Hence we combine the theoretical background of tax competition research with recent development in estimation methods, to explain strategic interaction between European governments.

Keywords: *Tax Competition, Tax Reaction Function, Spatial Autoregressive Model, GS2SLS*

JEL-Codes: *C33, C52, H20, H73*

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1. Motivation

Strategic interaction among governments has become an important research field in public economics. Zodrow and Mieszkowski (1986) and Wilson (1986) introduced the first formal theoretical model framework in order to explain the behaviour of governments to attract additional tax base. Case, Rosen, and Hines (1993) introduced the first econometric setting to explain interaction among governments in determining the level of public expenditures. These two fields of research have evolved almost separable over the last two decades. Econometric studies first focused on interaction among municipals. In recent years a small number of studies started to invest interaction among national governments, despite the problem of comparing different tax systems in an accurate way. Most recently Devereux, Lockwood, and Redoano (2002) combined these two fields of research. In their study they modified the ZMW - model, explaining both, tax rate and tax base competition, to finally test their theoretical results with a European panel data set. However, they also relied on a set of explanatory variables, recommended in former econometric studies.
The main goal of this study is to add another step in combining these two fields of literature. We will use some theoretical findings of the tax competition literature based on an endogenous growth framework. But in contrast to previous studies we will try to implement the results found in these contributions, into the set of explanatory variables. This procedure will add two distinctive aspects to the discussion of strategic interaction among governments. First we will test an econometric setting aiming to explain interactions among governments, incorporating theoretical results from the tax competition literature. Second we will estimate the model using a generalized spatial two stage least squares procedure, which - to our knowledge - was not implemented in any applied research project in this line before. This estimation procedure was introduced by Kelejian and Prucha (1997).

The remainder of this paper is organized as follows. In section 2.1 we discuss related research contributions to give a more precise introduction into the topic of strategic interaction from the theoretical as well as from the econometric side. Section 2.2 provides an up to date overview on capital income taxation in Europe. Section 3. starts with the theoretical background and explains the implementation of these results in the econometric framework. Further we discuss basic econometric difficulties, which we face in the model setting (section 3.2.2 and 3.2.3). Additionally we state the theoretical considerations to estimate the spatially autoregressive model with the GS2SLS procedure (section 3.2.5). In section 3.3 we explain in detail, which data we use to estimate the model, specially focusing on the newly introduced explanatory variables..

2. Theoretical Considerations and Empirical Evidence

2.1. Literature Overview

The fiscal-political question – hence a question for theoretical and empirical economic research – whether taxes are set too high, or too low, hence governments over- or underbid the sufficient and efficient amount of public goods, was originally raised by Oates (1972, 143), who noted: *"The result of tax competition may well be a tendency toward less than efficient levels of output of local services. In an attempt to keep taxes low to attract business investment, local officials may hold spending below those levels for which marginal benefits equal marginal costs, particularly for those programs that do not offer direct benefits to local business.".* Zodrow and Mieszkowski (1986) and Wilson (1986), denoted here as the ZMW-model, were the first ones to formalize these ideas. In order to attract foreign capital, jurisdictions reduce the tax rate on the mobile factor capital below the social optimum. Given that the tax cut is a non-compensated one, second that additional tax revenues paid by new firms entering the market do not compensate for the foregone revenues and third that the government faces a balanced budget constraint, total revenues will shrink, hence government spending will have to decline. This in turn induces a reduction in the level of output. Zodrow (2003)

summarized various modifications and extensions of the ZMW-model, which were presented in the subsequent years.
Public choice theory developed another access to the problem of decreasing capital taxes that stands in contrast to the tax competition literature. Within this theory policy makers try to maximize their own utility by increasing their fraction on the overall budget, which yields a bigger budget than the efficient one. Therefore the government levies higher taxes than in the social optimum. Hence a tax cut has a positive effects for the model economy. Such a reduction is considered as a chance to avert the Leviathan and at the same stage to reduce government waste. This surplus should be used for more reasonable expenditures, which should yield higher economic growth. Josten and Truger (2003) provide a detailed survey on this political-economy literature.
Besides further contributions in the above presented literature streams, also endogenous growth theory, see Myles (2000) for a survey, and the new economic geography were engaged in the question of tax competiton versus tax harmonisation. While the latter explains higher tax rates in core countries compared to lower tax rates in countries at the periphery, most contributions in the line of endogenous growth theory finally find high capital taxation in the first period and low or even zero capital taxation in the steady state. Many of those contributions include simulation results for their model economies, but some setups are also tested empirically, mainly with US data sets.

In the last years there has also been a great amount of econometric studies, going further into several empirical relevant questions of taxation. All these studies have in common that they face a serious data problem. The tax burden of an individual (or a company) depends upon the tax rate as well as the tax base. This induces a great difficulty for measurement, which gets even worse in a spatial analysis. Today, theory broadly distinguishes between measures based on tax legislation and measures based on tax revenues. Devereux, Griffith, and Klemm (2002) provide a comprehensive theoretical survey on corporate income taxation. They also present detailed stylized facts for a sample of sixteen OECD countries.
Beside this common problem recently published econometric studies widely differ in their addressed topics. At least two big fields can be identified. The first concentrates on growth regressions, which also include fiscal policy variables, such as capital income taxation; see Levine and Renelt (1992) for the most comprehensive study in this direction and Kalaitzidakis, Mamuneas, and Stengos (2000) for an extension to a non-linear analysis. Besides, some studies are concentrating on the effects of the tax structure on economic growth, see Lee and Gordon (2005) or Widmalm (2001), or the effects of taxation within an endogenous growth setting (Bleaney, Gemmell, and Kneller, 2001). Other research groups have focused their empirical questions on multinational, neoclassical, general equilibrium models, where they develop a considerably big model, which is brought to data, see e.g. Mendoza and Tesar (2005), Mendoza and Tesar (2003) or Mendoza (2001). The second important topic emphasises the role of FDI within the interaction of tax rates with additional investments and growth, see Devereux and Griffith (2002) for a survey.
This project follows another research direction. It builds on some recent contributions on strategic interaction between governments acting as fiscal authorities. These studies derive tax reaction functions in order to answer, how countries should optimally act within the tax competition situation given in the last years. Such tax reaction functions measure the response in the setting of one country's tax rate on a change in another country's tax rate.
Looking at previous work in this field we can distinguish two approaches. On the one hand some studies are concerned with the net effects of taxation and government spending. Case et al. (1993) was the first contribution in this direction; see Baicker (2005) for a recent update of this contribution, which also includes a comprehensive overview of articles published in recent years. On the other hand there are many studies asking the question, how local governments strategically interact, see e.g. Brueckner (1998), Brett and Pinkse (2000) or Heyndels and Vuchelen (1998) for studies on business property tax rates, Buettner (2001) for a study on jurisdictions in Germany or Hayashi and Boadway (2001) for a study on jurisdictions in Canada. However, as far as we could figure out, only four studies have tried to analyse this question taking individual countries as acting agents. These

are: Besley, Griffith, and Klemm (2001), Devereux et al. (2002), Altshuler and Goodspeed (2002) and Redoano (2003).
Redoano (2003) estimates reaction functions for capital and income taxes as well as public expenditures with a data set on EU countries for the period 1985 – 1995. In doing so Redoano mainly relies on the concept proposed by Case et al. (1993). Thus the emphasis lies in the reaction upon different government expenditures policies. Altshuler and Goodspeed (2002) also concentrate on European countries (using data from 1968 – 1996) but in contrast to Redoano they build a simple model comparing a Nash solution to a modified version, including a Stackelberg leader (USA) followed by Nash playing European countries. Devereux et al. (2002) set up a comprehensive model framework to explain both statutory tax and tax base competition (in OECD countries for the years 1982 – 1999). They extend the basic ZMW-model by integration of strategic interaction (in the setting of the statutory tax rate) and the opportunity for firms to shift profits.

2.2. Some Stylized Facts

After giving a brief overview on the most important literature contributions and before getting into the detailed model framework, we will present some stylized facts. We have pointed out that cross country studies are especially difficult due to the complexity of comparing tax regimes in different countries. Therefore we analyse several capital income tax measures, which have been currently used in recent studies. Although we apply only basic descriptive statistical tools, we can figure out two main messages that are in line with the research question of this paper.

- Effective capital income tax rates have fallen over the last 25 years. Implicit capital income tax rates have remained fairly stable from 1965-1995 and increased slightly thereafter. Some people call this downward trend a 'race to the bottom'.
- Corporate income tax rates converged within the last 25 years, measured by comparing the standard deviation and the spread for the single years. This convergence could be interpreted as more coordination (or interaction) between European countries. Hence the data set strengthens the prediction of this paper – about government interaction in Europe.

In principle there are two measures of corporate income taxes. The first group is based on measures defined upon the tax legislation. This group includes statutory tax rates, the net present value of depreciation allowances and effective marginal (EMTR) and effective average tax rates (EATR). These measures are forward looking and capture the impact of capital taxation on expected earnings on a specific investment in the future. EMTR and EATR combine the tax rate and the tax base in one number. Both measure the impact of the tax system on a hypothetical investment that just earns the minimum, or some, required rate of return. The calculation of these rates depends on the type of investment project, as well as the tax system itself. Normally the form of investment project has to be rather simple. The approach chosen for the calculation of the EMRT and the EATR, presented in this paper, is explained in Devereux et al. (2002, 461). As a certain profit assumption is included in the calculation of the EATR, which is proportional to the difference between the pre-tax and the post-tax required rate of return, compared to the EMTR, where an investment project is assumed that just breaks even, the EATR has a higher value than the EMTR. Hence the EATR lies above the EMTR.
The second group of measures is based on tax revenue data, thus they are backward looking. In Appendix A we present some stylized facts based on a country set of 15 countries from 1965-2005.[1] In the text we will explain main aspects of the different measures and highlight some stylized facts drawn from the dataset.[2]
In a first step, we compare the effective capital income tax rates (figure 1 and figure 2) and implicit

[1]The analysis on effective tax rates includes the EU15 countries, except Denmark and Luxembourg, plus Norway. The analysis of the implicit tax rates includes the EU15 countries, except Luxembourg, plus Norway.
[2]For a comprehensive overview see (Devereux et al., 2002)

capital income tax rates (figure 3). We can clearly indicate a downward trend in all three effective tax rates, especially from 1982 onward.[3] In figure 2 the effecitive tax rates are weighted by the relative size of GDP of the single country, compared to the GDP sum of all countries. Comparing the average weighted time series to the median time series we figure out a slower and smaller downward trend. Looking at the implicit tax rates we observe an almost stable trend from 1965-1995, an increase in the late nineties but again a decrease since 2000 (figure 3). We consider the implicit tax rates on capital evaluated by Eurostat on the one hand, and corporate income taxes as a fraction of GDP and total tax revenues as listed in code 1200 in the standard OECD classification on the other hand. Nevertheless this divergent trend seems to be inconsistent with the trends observed for effective capital income tax rates. Devereux et al. (2002, 472) try to explain this fact with two arguments. First profitability of the firms have changed and second this upward trend is probably caused by the tax system itself – pointing at the example of Ireland.

In a second step we take a closer look at the single effective tax rates. In figures 4, 5 and 6 we plot the median over all countries over time, compared to the standard deviation of all countries in one year over the observation period. The standard deviation acts as one possibility to measure the divergence of tax rates.[4] Again all three figures show a similar pattern. The tax rates are falling over time and so do the standard deviations. In figures 7, 8 and 9 we plot the statutory tax rate, the EMTR and the EATR for all countries, comparing the years 1982 and 2005. Although we figure out a common downward trend we also observe big differences for single countries. We note that all countries except Ireland, Spain and Italy have articulately reduced the rates, Ireland was forced to increase its capital taxation, Spain and Italy kept almost at the same level.

In order to explain rising tax revenues (standardized with respect to GDP and total revenues) compared to decreasing tax rates we have to consider the tax base. However the definition for the corporate tax base is highly involved. Therefore we use depreciation allowances for capital expenditures (allowances in their present discounted value (PDV)), as suggested by empirical literature. A high PDV of depreciation allowances gives a company the possibility to reduce its profits immediately, hence to reduce the tax burden. Contrary a low PDV of depreciation allowances allows companies only to depreciate a fraction in the year of investment, hence a low PDV of depreciation allowances implies a broader tax base. If we look at the data we can figure out a decrease in the PDV of depreciation allowances indicating a broadening of the tax base the last years. Except Spain, Portugal and Italy all countries have expanded their tax base. Sweden, Holland and Belgium kept their allowances on the same level (figure 12). This trend is summarized in figures 10 and 11, which show the overall development of a decreasing PDV of depreciation allowances. As in the case of the tax rates, we also observe a decreasing standard deviation for the PDV of depreciation allowances.

Last we have a detailed look on implicit tax rates, which are shown in figures 13, 14, 15 and 16. Mean and standard deviation behave rather constant over time. The mean over all countries started increasing significantly in 1995, but is again falling since 2000. The standard deviation is almost constant at one level, except for a period in the early eighties and the years after millennium. A look on the single country trends prevails that the overall trend may be dominated by some single countries. While in Austria, France, Holland and Sweden tax revenues have kept almost stable we have seen rigorous changes in Norway (due to tax income from oil companies) or Spain and Ireland, presumable due to an economic boom.

[3]For the years 1979 - 1982 we do not have data for Austria, Belgium, Norway, Portugal and Sweden.

[4]The spread between the maximum and the minimum tax rate within one year would be another measure, but is not plotted here. The spread has also decreased over the observation period.

We sum up these observed trends in some stylized facts:

- **Stylized fact 1:** Effective rates, i.e. statutory tax rates, EMTR and EATR, have fallen but converged over the last 25 years.
- **Stylized fact 2:** For the same time period we observe on average a broadening tax bases.
- **Stylized fact 3:** Implicit tax rates have remained almost stable over the last 40 years, with a slight upwards trend in the last 10 years.

3. The Model

3.1. Theoretical Considerations

Lejour and Verbon (1997) examine theoretically the effects of policy coordination in a two-country, contiuous time, endogenous growth set up with imperfect capital mobility and no trade. The model is based on the Arrow 'learning-by-doing' approach. They assume two identical countries populated with workers and capitalists and a government that provides a public (infrastructure) good. Workers do not pay taxes, capitalists pay a source-based tax on capital income. They explicitly determine a tax-base externality[5]. Based on this model setting they calculate optimal tax- and growth rates for the cases of uncoordinated and coordinated governments. The uncoordinated case can not yield an optimal outcome in the Nash equilibrium, as the governments do not account for the effects in the other country. In the coordinated case they assume a central authority that accounts for these spillover effects. This international coordination effects the level of output via the tax-base externality and the growth rate via the growth externality[6] [7]. They explicitly determine the two externalities for the coordinated case (see Lejour and Verbon, 1997, 492) and state a condition such that the growth externality dominates the tax base externality. (Then a decrease in the foreign tax rate results in an increase in the home tax base.) In the noncoordinated case the produced amount of the public good is inefficiently high, thus economic growth is lower than in the coordinated case. This result turns around if the tax base effect dominates the growth externality.

Beside these findings they also derive the tax reaction functions for the non-coordinated – empirical relevant – case and conclude, *"The reaction curves have a positive slope."* (Lejour and Verbon, 1997, 495). The functional setting of the reaction function is rather complicated [8], however, we only care about those variables that appear in the functional setting.

$$\tau = R\left(\delta, \mu, \pi, \pi^{*}\rho, \tau^{*}, Inv, K^{s}, K^{d}, r, r^{*}\right) \tag{2}$$

[5]A change in the tax on capital income has a level effect. Assume a decrease in the foreign tax rate on capital income. This will induce a reallocation of the invested capital from the foreign into the home country, having a negative (level) effect on the tax base in the home country.

[6]A change in the tax on capital income has also a growth effect. Assume again, a decrease in the tax rate in the foreign country, thus foreign net returns increase, holding everything else fixed. As the income of the capitalists (who invest in both countries) is bigger, they save more, thus the new tax rate induces a higher growth of savings. Now these capitalists will also invest more in the home country, which now increases the growth of invested capital, the growth of labour income and finally the tax base in the home country.

[7]This externality is a result of the endogenous growth setting, as in an exogenous growth model an increase in the tax rate in the home country would have no effect on the total stock of invested capital in the foreign country.

[8]The reaction function is given by

$$-\frac{\delta}{\tau^{2}}d\tau - \frac{(1+\delta)\,r}{K^{s}\left(K^{d}\right)^{2}}\left(\frac{K^{s}(2Inv-K^{s})}{\mu}+\frac{(K^{s}-Inv)Inv}{\rho}\right)\left(\frac{\partial K^{s}}{\partial \tau}d\tau - \frac{\partial K^{s*}}{\partial \tau^{*}}d\tau^{*}\right) + \frac{(1+\delta)\,r}{\rho\mu\left(K^{d}\right)^{2}}\left[\frac{\rho}{\mu}\left(K^{s}+K^{s*}\right)^{2}\right]\left(\frac{\partial \pi}{\partial \tau}d\tau - \frac{\partial \pi^{*}}{\partial \tau^{*}}d\tau^{*}\right) = 0 \tag{1}$$

(see Lejour and Verbon, 1997, 495)

where δ is described in the following way, *"If the public good is interpreted as social insurance, the parameter δ might be interpreted as the relative probability of the 'bad' state occurring. So, a low (high) value of δ then corresponds with a low (high) degree of uncertainty experienced by the workers."* (see Lejour and Verbon, 1997, 496); μ describes the effects of imperfect information that firms face when they invest abroad; π is the growth rate of the home country; ρ is the rate of time preference in the utility maximisation; Inv are foreign investments; K^s is the total capital stock; K^d is capital invested in the home country; r is the return on capital in the home country and the asterisk refers to variables related to the foreign country.

3.2. Empirical Implementation

3.2.1. From the theoretical to the empirical model

The empirical specification will closely follow the work of Michela Redoano (2003). Thus we will also follow the specification worked out by Case et al. (1993) to test the interdependencies of international tax competition. The tax reaction function in (1) is the starting point for the specification of the empirical model. The tax measure, denoted by τ of country i in year t depends upon the tax measure of the other countries $(-i)$ and its own preferences, summarized in the vector $\mathbf{X}$, which were explicitly described in (2).

$$\tau_{it} = R_i\left(\tau_{-i,t}, \mathbf{X}_{it}\right) \tag{3}$$

The considered base studies use a varity of variables for the vector $\mathbf{X}$. These are shown in figure 17 in the appendix. In this study we account for the theoretical considerations of the endogenous growth setting and implement various new characteristics (k) in the vector $\mathbf{X}$. We will include a measure for the capital stock, an interest rate measure, a measure of economic growth and a measure that takes into account the costs of investing abroad. As already done in Redoano (2003) and Devereux et al. (2002) we will also include a measure that considers the FDI flows. The empirical version of (1) for one neighbor country j has the following form

$$\tau_{it} = \theta\tau_{jt} + X_{it}\beta + u_{it} \tag{4}$$

where β and θ are unknown parameters and u_{it} is the vector of regression disturbances and will be further specified on the next page, when we discuss the problem of spatial error dependece.
In order to account for the possibility of more than one neighbor country we include a weighting matrix that accounts for the impact of the other countries. Case et al. (1993, 292) note that *"it would be desirable to estimate the elements of the W matrix along with the other parameters. In practice, such an approach is out of the question because of insufficient degrees of freedom."* Therefore the weighting matrix is *a priori* defined and can be modelled in several ways.[9] The exact specification of the weighting matrix for this research project is introduced later. For the moment we replace τ_{jt} in (4) by

$$T_{it} = \sum_{j=1}^{n} w_{ij}\tau_{jt} \tag{5}$$

where $\sum_{j=1}^{n} w_{ij} = 1$ and $w_{ij} = 0$ if country j is not a 'neighbor' or if $j = i$. The weighting matrix is of size $(I \times I)$, where $i = 1, 2, \ldots, I$. Now we can rewrite (4) to get

$$\tau_{it} = \theta T_{it} + X_{it}\beta + u_{it} \tag{6}$$

[9](Case et al., 1993) use weights on geography, per capita income and proportion of black population; (Devereux et al., 2002) use uniform weights, weights based on the size of the economy and on the openness of the economy; (Altshuler and Goodspeed, 2002) use only geographic weights and (Redoano, 2003) uses geographical weights, weights based on GDP differences and on GDP per capita basis.

or written as as system of tax equation for all the countries in year t in matrix form

$$\tau_t = \theta T_t + X_t\beta + u_t \tag{7a}$$
$$= \theta W\tau_t + X_t\beta + u_t \tag{7b}$$

where τ_t is a $(2I \times 1)$ vector; θ and β are the respective coefficients and X is a $(2I{\times}k)$ matrix of explanatory variables.

On the RHS of equation (7) we face two econometric issues that have to be addressed at this point: endogeneity of the tax rates and possible spatial error dependence. In the spatial econometrics literature a specification like in equation (7) is known as a spatial lag model. (see Anselin, 1988)

3.2.2. Endogeneity

Based upon the strategic interaction assumption between the single countries, the tax rates in (7) are jointly determined, hence endogenous and correlated with the error term. To see this explicitly we rewrite equation (7)

$$\tau_t = (I - \theta W)^{-1} X_t\beta + (I - \theta W)^{-1} u_t \tag{8}$$

In equation (8) τ_t is equal the inner product of the kth row of the matrix $(I - \theta W)^{-1}$ and the error vector u_t plus a second inner product. Hence each entry in the τ_t vector depends on all error terms. Thus each of the τ_t in equation (7b) on the RHS also depends on u_t. This results in an inconsistent OLS estimator for the parameters in equation (7) – requiring use of an alternative estimation method. Two methods are widely used in the literature, first estimating the reduced form of equation (8) using maximum likelihood (ML) methods[10] or secondly to use an instrumental variables (IV) approach, which we will describe in more detail later.

3.2.3. Spatial Error Dependence

In this model setting we cannot assume that the error terms are independent across jurisdictions as we have to account for correlated random shocks facing more than one country. We will also face spatial error dependence if the error term includes omitted variables not captured in the vector of characteristic variables X. Hence errors could exhibit spatial dependence and in order to account for this dependence we define

$$u_t = \lambda M u_t + v_t \tag{9}$$

where λ is an unknown autoregressive parameter, M is a new weighting matrix and v is a vector of 'innovations'. Following Assumption 5 in Kelejian and Prucha (1997, 4) we assume $v_t \sim i.i.d.(0, \sigma_v^2)$. To simplify the estimation we assume $M = W$, which is an assumption made in all base studies.[11] If spatial dependence in v_t is ignored the estimates itself, are not biased[12] but inefficient. To account for this second problem, two methods are normally proposed, first using ML and taking into account the error structure or showing error independence and second using an IV estimation procedure.

Before we turn to the explanation of the exact estimation procedure we have to specify the choices of the weighting matrix W.

[10] see e.g. Case et al. (1993)

[11] Kelejian and Prucha (1997, 10) note that λ could be consistently estimated wheater or not W and M are equal or not.

[12] But the standard errors will be biased

3.2.4. The Choice of the Weights

In this research work we will examine three different weighting matrix schemes. As noted above the weighing matrix W is *a priori* determined and mearsures the 'closeness' of two countries.

First we consider a geographical weighting in the form of a contiguity matrix. If two countries share a border, the value 1 is assigned and zero otherwise, these weights are normalized to add to one across rows and columns. In assigning weights to neighbors we have ignored small bodies of water seperating countries. Assume for example only EU 15 countries, then Austria only shares a common boarder with Germany and Italy. Hence one has to be divided through two and $\frac{1}{2}$ has to be assigned to each weight in the matrix, e.g.

$$w^{geo}_{Austria,Germany} = w^{geo}_{Austria,Italy} = \frac{1}{2} \tag{10}$$

in the $(I \times I)$ weighting matrix. A complete list of the neighbors for the EU 15 countries, without Luxembourg and Denmark, plus Norway is summarized in table 2 in the appendix.

Second we consider a weighting matrix that is based on the economic strength, measured by GDP per capita. Two countries with similar economic strength are 'closer' to each other, compared to two countries with different economic strength, e.g.

$$\omega^{eco}_{ij} = 1 - \frac{|GDP_i/POP_i - GDP_j/POP_j|}{max\,(GDP_i/POP_i, GDP_j/POP_j)} \tag{11a}$$

$$w^{eco}_{ij} = \frac{\omega^{eco}_{ij}}{\sum_j \omega^{eco}_{ij}} \tag{11b}$$

A third approach is based upon the openess of the economy. A country with a higher degree of openess is 'closer' to another country. Openess will be measured by the fraction of the sum of imports (Im) and exports (Ex) relative to GDP, e.g.

$$\omega^{open}_{ij} = 1 - \frac{|\frac{Im_i+Ex_i}{GDP_i} - \frac{Im_j+Ex_j}{GDP_j}|}{max\left(\frac{Im_i+Ex_i}{GDP_i}, \frac{Im_j+Ex_j}{GDP_j}\right)} \tag{12a}$$

$$w^{open}_{ij} = \frac{\omega^{open}_{ij}}{\sum_j \omega^{open}_{ij}} \tag{12b}$$

Throughout the model we assume a fixed weighting matrix W, therefore we will check if W^{eco} and W^{open} fluctuate over the estimation period by looking at the standard deviation and a ranking of all countries in the sample. We will account for this problem, if necessary. Now we can turn to the discussion of the estimation technique.

3.2.5. Estimation Technique

Facing the same type of a spatial lag model the four base studies have applied different estimation procedures, Case et al. (1993) use a ML approach, Altshuler and Goodspeed (2002), Devereux et al. (2002) and Redoano (2003) use an IV approach. The latter three studies apply a two step procedure. Instead we will use a three step estimation procedure which is based on the work by Kelejian and Prucha (1997) who introduce a generalized spatial two stage least squares (GS2SLS) method.[13]

[13]For the moment, we omit the inclusion of a time- and country specific trend. We will account for this enhancement in the section on estimation and results, if necessary.

To explain this estimation procedure and in order to state the key equations we need some more formal notation of the model. First we rewrite (7) taking into account the spatial error dependence of the error term. In a second step we transform this to a more compact version of (13a). In a third step we rewrite (13b) after applying the Cochrane-Orcutt type transformation and account for the error term.

$$\begin{aligned} \tau_t &= \theta W \tau_t + X_t \beta + u_t \\ u_t &= \lambda W u_t + v_t \end{aligned} \tag{13a}$$

$$\begin{aligned} \tau_t &= Z_t \xi + u_t \\ u_t &= \lambda W u_t + v_t \end{aligned} \tag{13b}$$

$$\tau_{t*} = Z_{t*} \xi + v_t \tag{13c}$$

where $Z_t = (X_t, W\tau_t)$ and $\xi = (\beta', \theta)'$; $\tau_{t*} = \tau_t - \lambda W \tau_t$ and $Z_{t*} = Z_t - \lambda W Z_t$

Now we define a subset (X_t^*) of the set of the charcteristic variables (which form the vector $\mathbf{X}$) to build a matrix of natural instruments $(\mathbf{H})$, e.g.

$$H_t = (X_t, W X_t^*) \tag{14}$$

where the intruments $\mathbf{H}$ are based on the vector of characteristics $\mathbf{X}$ and a subset of those characteristics $\mathbf{X}^*$ weighted with the spatial lags of the characteristics $\mathbf{W}$.

In the first step of the procedure we estimate (13*b*) by two stage least squares (2SLS) using the instrument defined in (14).

$$\begin{aligned} \hat{\xi} &= \left(\hat{\beta}', \hat{\theta}\right)' = \left(Z_t' P_t Z_t\right)^{-1} \left(Z_t' P_t \tau_t\right) \\ P_t &= H_t \left(H_t' H_t\right) H_t' \end{aligned} \tag{15}$$

In the second step we account for the spatial error dependence and estimate the autoregressive parameter λ (which was introduced in (9)) in terms of the residual from the first step by the generalized moments (GMM) procedure introduced in Kelejian and Prucha (1995) and summarized in Kelejian and Prucha (1997). This second step provides a consistent estimator $\bar{\lambda}$.

In the third step we will estimate equation (13c) (which is the Cochrane-Orcutt transformed form from (13*b*) in order to account for the spatial correlation) by 2SLS. The final estimator has the following form

$$\begin{aligned} \tilde{\xi} &= \left(\tilde{\beta}', \tilde{\theta}\right)' = \left(\bar{Z}_t' P_t \bar{Z}_t\right)^{-1} \left(\bar{Z}_t' P_t \bar{\tau}_t\right) \\ \bar{Z}_t &= Z_t - \bar{\lambda} W Z_t \\ \bar{\tau}_t &= \tau_t - \bar{\lambda} W \tau_t \end{aligned} \tag{16}$$

Kelejian and Prucha (1997, 21) proof that $\tilde{\xi}$ is consistent.

Summing up, in this study we will estimate a single slope coefficient of a tax reaction function for a sample of European countries. This estimation will add two aspects to the current discussion of tax reaction functions in the literature. First we are using a new set of characteristic exogenous variables, which are theoretically based upon the endogenous growth paper by Lejour and Verbon (1997). Second, compared to the base studies, we will use the generalized spatial two stage least squares (GS2SLS) procedure in order to estimate the spatially autoregressive model introduced in this section consistently.

$$\begin{aligned} \tau_{it} &= \theta T_{it} + X_{it}\beta + u_{it} \\ u_{it} &= \lambda W u_{it} + v_{it} \end{aligned} \tag{17}$$

Having stated the estimation equation and the theoretical methods to estimate this function, we will now introduce the data set in detail before we come to the estimation results.

3.3. Data

We estimate model 17 using annual data on the EU15, except Luxembourg and Denmark, but including Norway over the period 1985-2005. The exact description of the variables is listed in the Data Appendix (section A.1). From the tax measures we will individually test the statutory capital income tax rate STAT, the effective marginal tax rate EMTR and the effective average tax rate EATR. To construct the weighting matrix we use data on imports, exports, GDP and GDP per head obtained from Eurostat.
The main difference to former studies in the area of strategic interaction lies in those variables used as explanatory variables. In a first step we recall equation 2 which summarizes all dependent variables in the tax reaction function.

$$\tau = R\left(\delta, \mu, \pi, \pi^{*}\rho, \tau^{*}, Inv, K^{s}, K^{d}, r, r^{*}\right) \tag{18}$$

Thus we we need empirical data for the capital stock, the interest rate, economic growth, the additional costs of investing abroad due to imperfect information and FDI flows. We will describe each measure seperately in detail:

- We will estimate the model with two differnt capital stock measures, CAPST1 and CAPST2. CAPST1 measures the private non-residuential net capital stock and CAPST2 measures the total net capital stock. Both time series where calculated for an IMF study on capital stocks in OECD countries. (Kamps, 2005).
- We have choosen nominal long-term interest rates INT to measure the rate of return on capital. They are a collection of interest rates on different long run bonds (usually with a duration of 10 years) for the different counties. Compared to a long run investment decision the rate of return on a long run bond can be seen as alternative riskfree investment, hence as an accurate measure for the rate of return. In addition with using these interst rates we omit the problem of a unified short run interest rate with the implementation of the Euro in 1998.
- Economic growth ECOGR is measured by the real growth rate of GDP at constant prices of 2000.
- Potentially there is no adequat measure for μ[14]. We try to account for this measure by two indices. First with the Industrial Confidence Indicator, INVAB1 and second with a measure that accounts for factors limiting production, INVAB2. Both do not account for the costs based on an imperfect information. However both of them give a certain market appraisal. If a company is not part of the market (but wants to invest in that market), it does not have full information, hence a wrong appraisal is likely. Instead of adjusting its production to the

[14] which describes the effects of imperfect information that firms face when they invest abroad

correct appraisal the firm has no information on the future. This wrong prediction results in a non optimal production, once the company has entered the market. Therefore these two indicators are supposed to be good substitutes for an accurate measure of additional costs due to imperfect information.

- We will use both investment inflows FDIin and outflows FDIout.

We notice that that Sweden, Great Britain and Norway do not have the Euro as all the other countries and hence we have to make those measures that are counted in currency units (GDP, Im, Ex, CapSt) compareable. Further we will account for missing data points and describe the exact procedure for both cases in the section on the estimation procedure.

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A. Data Appendix

A.1. Data description

Tax rate measures

STAT (Statutory tax rates):
Countries: Austria, Belgium, Finland, France, Great Britain, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden; Period covered: 1979-2005; Notes: "For countries using different tax rates, the manufacturing rate is chosen. Local taxes (or the average across regions) are included where they exist. Any supplementary taxes are included only if they apply generally, rather than only under particular circumstances." Devereux et al. (2002, 457); Source: `http://www.ifs.org.uk/data/internationaltaxdata.zip`, table A1.

PDV (Allowances in their present discounted value):
Countries: Austria, Belgium, Finland, France, Great Britain, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden; Period covered: 1979-2005; Notes: "The PDV of allowances is calculated for an investment in plant and machinery. Special first year allowances are included if applicable. Where switching between straight-line and reducing balance methods is allowed, such switching is assumed at the optimal print. The assumed real discount rate is 10%, the assumed rate of inflation is 3.5%." Devereux et al. (2002, 459); Source: `http://www.ifs.org.uk/data/internationaltaxdata.zip`, table A2.

EMTR (Effective marginal tax rates):
Countries: Austria, Belgium, Finland, France, Great Britain, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden; Period covered: 1979-2005; Notes: "Calculations based on a hypothetical investment for one period in plant and machinery, financed by equity or retained earnings (but not debt). Taxation at the shareholder level is not included. The project is expected to break even, i.e. there is no economic rent. Other assumptions – real discount rate: 10%, inflation rate: 3.5%, depreciation rate: 12.25%." Devereux et al. (2002, 462); Source: `http://www.ifs.org.uk/data/internationaltaxdata.zip`, table A5.

EATR (Effective average tax rates):
Countries: Austria, Belgium, Finland, France, Great Britain, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden; Period covered: 1979-2005; Notes: "Calculations base on a hypothetical investment for one period in plant and machinery, financed by equity or retained earnings (but not debt). Taxation at the shareholder level is not included. The expected rate of economic profits earned is 10% (implying a financial return, p , of 20%). Other assumptions: real discount rate: 10%, inflation rate: 3.5%, depreciation rate: 12.25%." Devereux et al. (2002, 464); Source: `http://www.ifs.org.uk/data/internationaltaxdata.zip`, table A9.

IMT_1 (Implicit tax rate):
Countries: Austria, Belgium, Denmark, Finland, France, Great Britain, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden; Period covered: 1995-2003; Notes: Data from the panel: Implicit tax rate on capital - total (ITR_CAP_TOT); Source `http://epp.eurostat.cec.eu.int/portal/page?_pageid=1996,45323734&_dad=portal&_schema=PORTAL&screen=welcomeref&open=/economy/gov/taxes&language=en&product=EU_MAIN_TREE&root=EU_MAIN_TREE&scrollto=0`

IMT_2 (Taxes on corporate income as percentage of GDP):
Countries: Austria, Belgium, Denmark, Finland, France, Great Britain, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden; Period covered: 1965-2003; Notes: Data are taken from the OECD Revenue Statistics code 1200. If two versions of the Revenue Statistics reported different values we took the value from the more recent version. Sources: Revenue Statistics 1965/1998 (1999 Edition), Revenue Statistics 1965-1999 (2000 Edition), Revenue Statistics: Special Features: Current Issues in Reporting Tax Revenues - The Impact of GDP Revisions 1965/2000 2001 Edition, Revenue Statistics 1965-2003 - 2004 Edition and Revenue Statistics 1965-2004 - 2005 Edition; on `http://puck.sourceoecd.org/vl=4962086/cl=30/nw=1/rpsv/book/b17_about.htm?jnlissn=99980169`

IMT_3 (Taxes on corporate income as percentage of Total tax revenues):
Countries: Austria, Belgium, Denmark, Finland, France, Great Britain, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden; Period covered: 1965-2003; Notes: Data are taken from the OECD Revenue Statistics code 1200. If two versions of the Revenue Statistics reported different values we took the value from the more recent version. Sources: Revenue Statistics 1965/1998 (1999 Edition), Revenue Statistics 1965-1999 (2000 Edition), Revenue Statistics: Special Features: Current Issues in Reporting Tax Revenues - The Impact of GDP Revisions 1965/2000 2001 Edition, Revenue Statistics 1965-2003 - 2004 Edition and Revenue Statistics 1965-2004 - 2005 Edition; on `http://puck.sourceoecd.org/vl=4962086/cl=30/nw=1/rpsv/book/b17_about.htm?jnlissn=99980169`

Weighting Matrix

GDP:
Countries: Austria, Belgium, Denmark, Finland, France, Great Britain, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden; Period covered: 1965-2003; Notes: Data from the panel: Gross domestic product at market prices (B1GM), Gross domestic product at market prices, Millions of euro (at 1995 prices and exchange rates); Source: `http://epp.eurostat.cec.eu.int/portal/page?_pageid=1996,45323734&_dad=portal&_schema=PORTAL&screen=welcomeref&close=/economy/bop&language=en&product=EU_MAIN_TREE&root=EU_MAIN_TREE&scrollto=137`

Im and Ex (Imports and Exports):
Countries: Austria, Belgium, Denmark, Finland, France, Great Britain, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden; Period covered: 1979-2005; Notes: Imports and exports seperated, both including goods and services (at 1995 prices and exchange rates); P6 and P7, Millions of euro (at 1995 prices and exchange rates; Source: `http://epp.eurostat.cec.eu.int/portal/page?_pageid=1996,45323734&_dad=portal&_schema=PORTAL&screen=welcomeref&open=/economy/nation/aggs/aggs_exi&language=de&product=EU_MAIN_TREE&root=EU_MAIN_TREE&scrollto=0`

GDP/head:
Countries: Austria, Belgium, Denmark, Finland, France, Great Britain, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden; Period covered: 1995-2005; Notes: GDP per capita in Purchasing Power Standards (PPS), (EU-25=100); EB011; Source: `http://epp.eurostat.cec.eu.int/portal/page?_pageid=1996,45323734&_dad=portal&_schema=PORTAL&screen=welcomeref&open=/basic/strind/ecobac&language=de&product=EU_MAIN_TREE&root=EU_MAIN_TREE&scrollto=0`

Explanatory Variables

CAPST1 (capital stock):
Countries: Austria, Belgium, Denmark, Finland, France, Great Britain, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden; Period covered: 1979-2002; Notes: Private non-residential net capital stock (capital stock of the business sector), volume (billions of national currency); Source: `http://www.uni-kiel.de/IfW/forschung/netcap/netcap.htm`

CAPST2 (capital stock):
Countries: Austria, Belgium, Denmark, Finland, France, Great Britain, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden; Period covered: 1979-2002; Notes: Total net capital stock, volume (billions of national currency), beginning-of-year stock , volume (billions of national currency); Source: `http://www.uni-kiel.de/IfW/forschung/netcap/netcap.htm`

INT (interest rate):
Countries: Austria, Belgium, Denmark, Finland, France, Great Britain, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden; Period covered: 1971-2004; Notes: Nominal long-term interest rates, exact definitions: Statistical Annex of European Economy, Autumn 2005, page 17, Source: `http://europa.eu.int/comm/economy_finance/publications/european_economy/2005/statannex0205_en.pdf`

ECOGR (economic growth):
Countries: Austria, Belgium, Denmark, Finland, France, Great Britain, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden; Period covered: 1979-2005; Notes: Growth rate of GDP at constant prices (2000) - Percentage change on previous year; EB012; Source: `http://epp.eurostat.cec.eu.int/portal/page?_pageid=1996,45323734&_dad=portal&_schema=PORTAL&screen=welcomeref&open=/basic/strind/ecobac&language=de&product=EU_MAIN_TREE&root=EU_MAIN_TREE&scrollto=0`

INVAB1 (costs of investing abroad):
Countries: Austria, Belgium, Denmark, Finland, France, Great Britain, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden; Period covered: 1985-2005; Notes: Industrial Confidence Indicator, Seasonally Adjusted Data; Source: `http://europa.eu.int/comm/economy_finance/indicators/business_consumer_surveys/bcsseries_en.htm`

INVAB1 (costs of investing abroad):
Countries: Austria, Belgium, Denmark, Finland, France, Great Britain, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden; Period covered: 1985-2005; Notes: Factors limiting the production (sum of 6 factors: None, Demand, Labour, Equipment, Other, Financial); Seasonally Adjusted Data; Source: `http://europa.eu.int/comm/economy_finance/indicators/business_consumer_surveys/bcsseries_en.htm`

FDIin (Foreign Direct Investments):
Countries: Austria, Belgium, Denmark, Finland, France, Great Britain, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden; Period covered: 1985-2003; Notes: inflows from OECD area, US dollars, source: `http://titania.sourceoecd.org/vl=8214360/cl=16/nw=1/rpsv/ij/oecdstats/16081080/v45n1/s5/p1`

FDIout (Foreign Direct Investments):
Countries: Austria, Belgium, Denmark, Finland, France, Great Britain, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden; Period covered: 1985-2003; Notes: inflows

from OECD area, US dollars, source: http://titania.sourceoecd.org/vl=8214360/cl=16/nw=1/rpsv/ij/oecdstats/16081080/v45n1/s5/p1

A.2. Figures

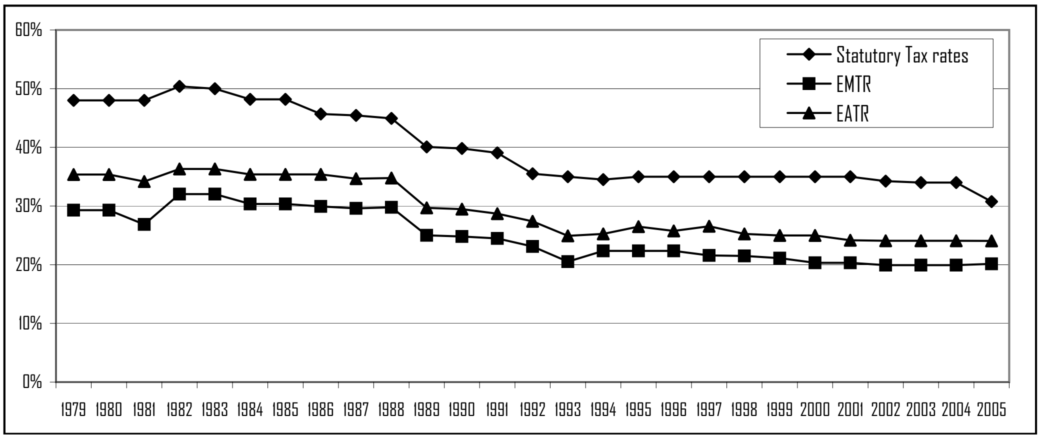

Figure 1: Effective tax rates, median

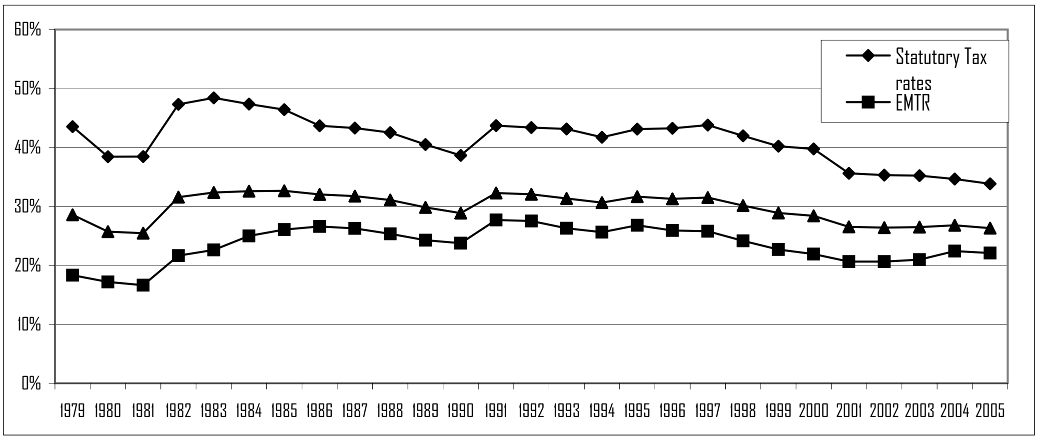

Figure 2: Effective tax rates, median

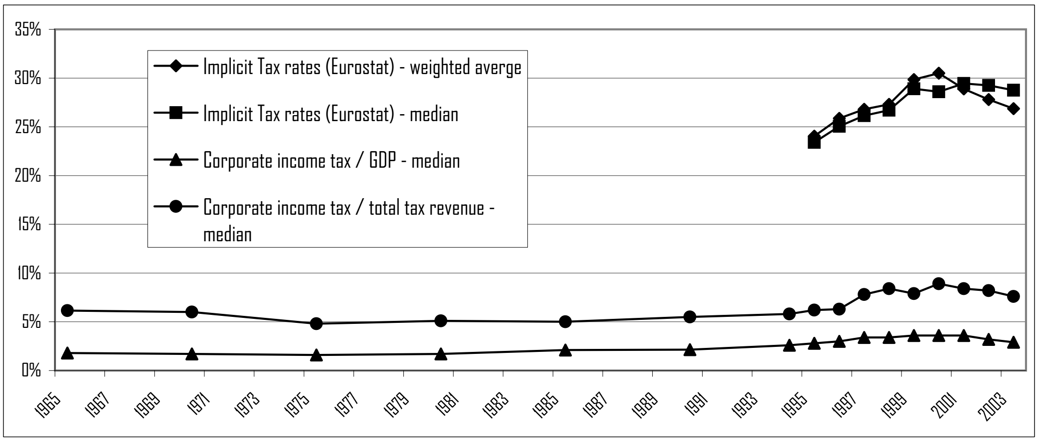

Figure 3: Implicit tax rates

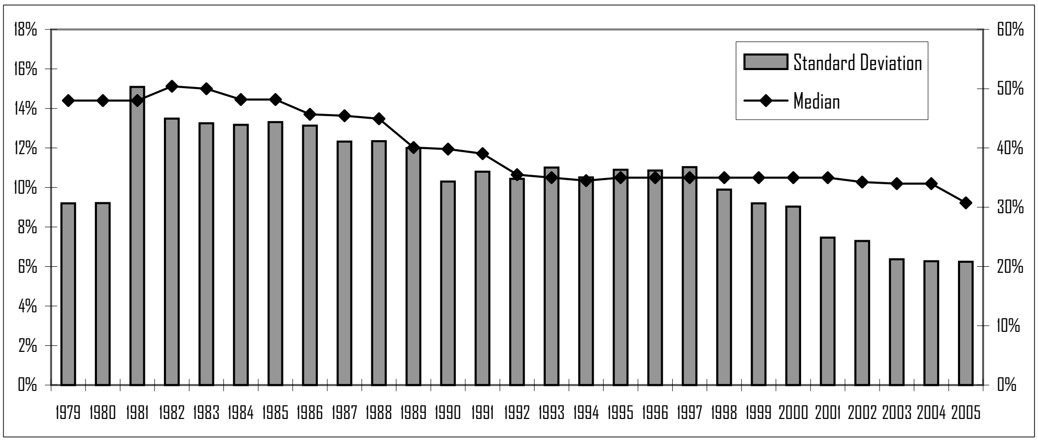

Figure 4: Statutory tax rates, median and standard deviation

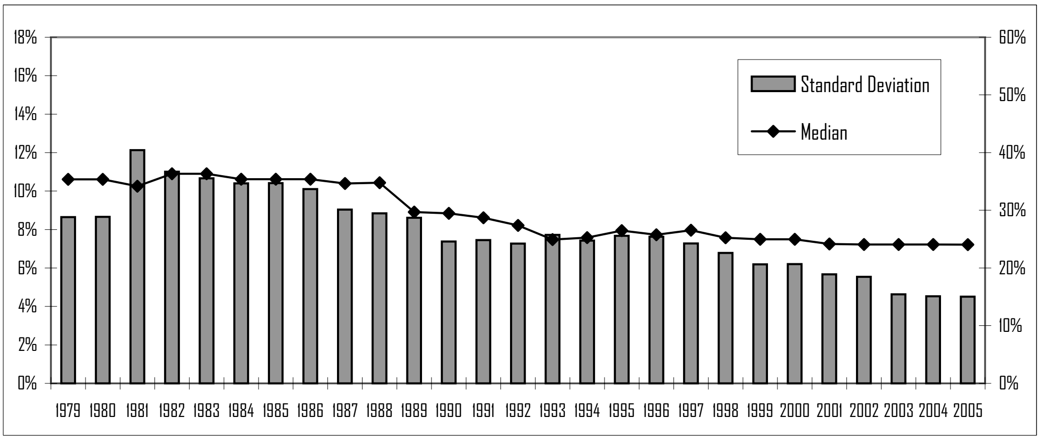

Figure 5: Effective marginal tax rate, median and standard deviation

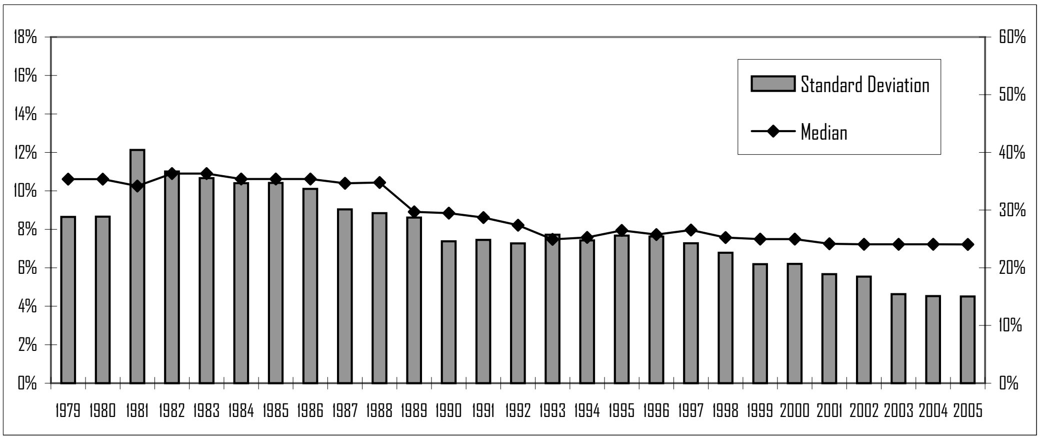

Figure 6: Effective average tax rate, median and standard deviation

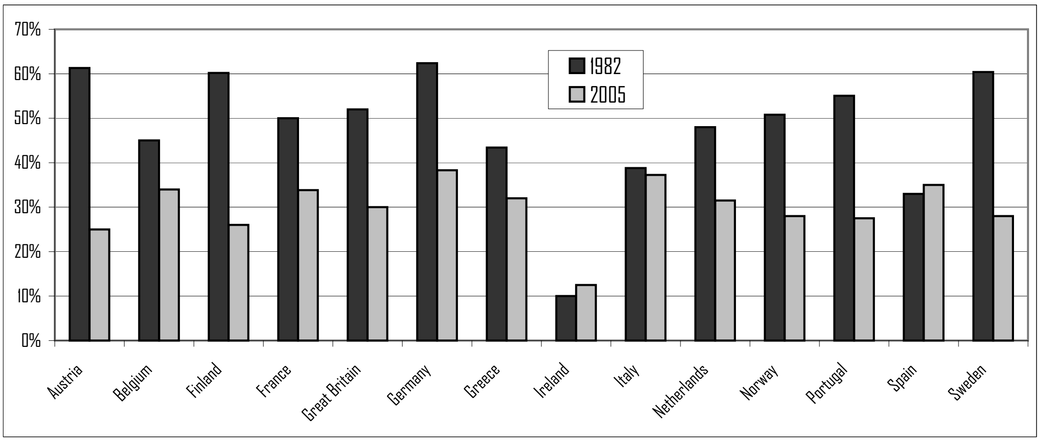

Figure 7: Statutory tax rates, country tables

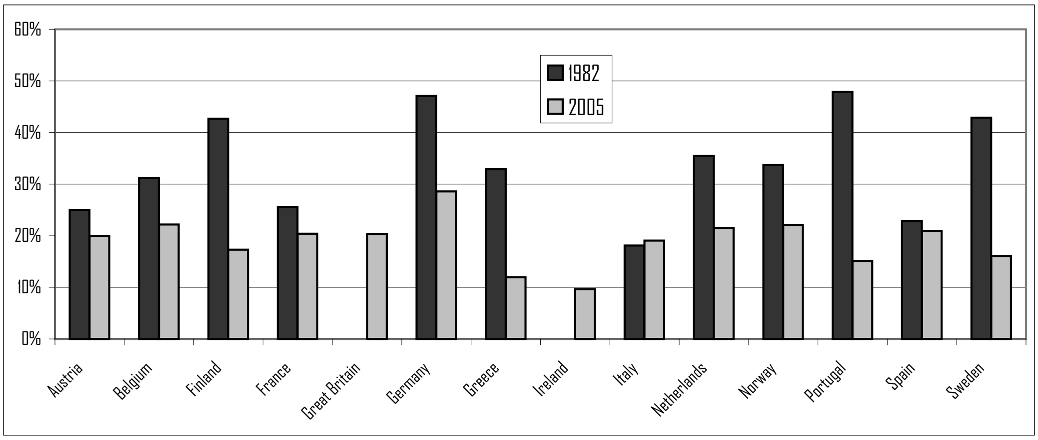

Figure 8: Effective marginal tax rate, country tables

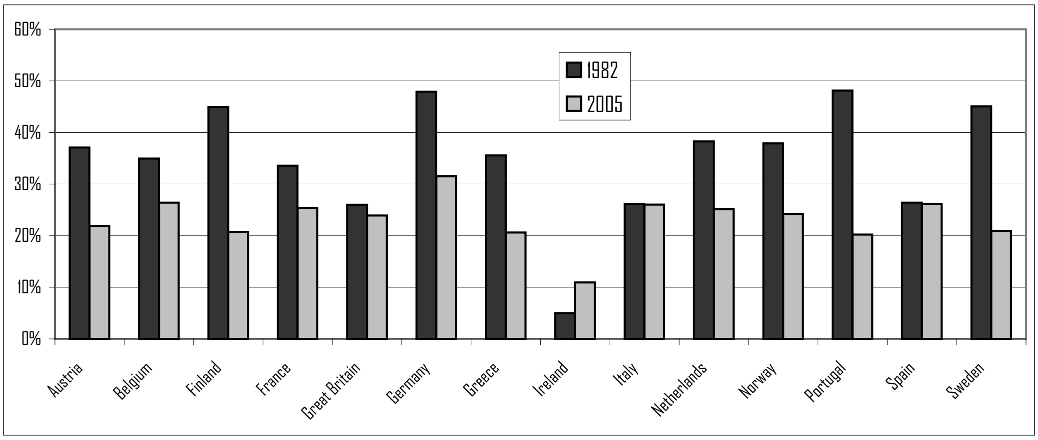

Figure 9: Effective average tax rate, country tables

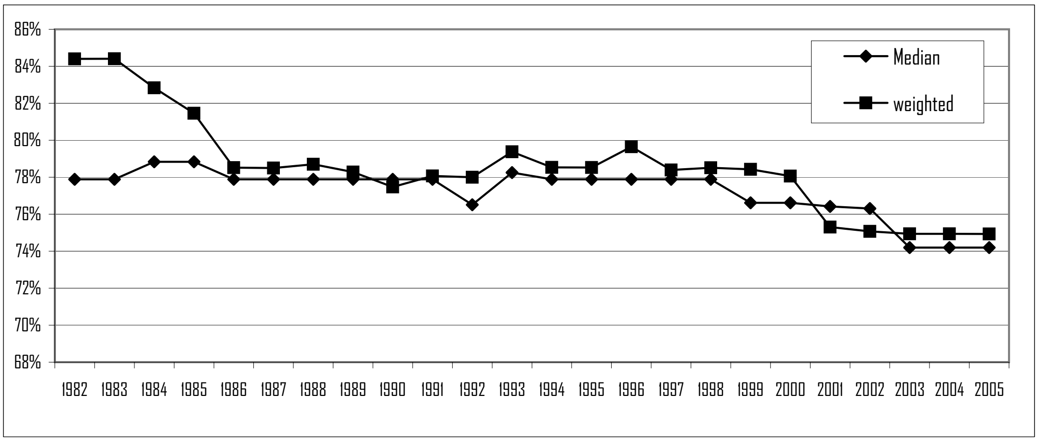

Figure 10: Allowences, median and weighted average

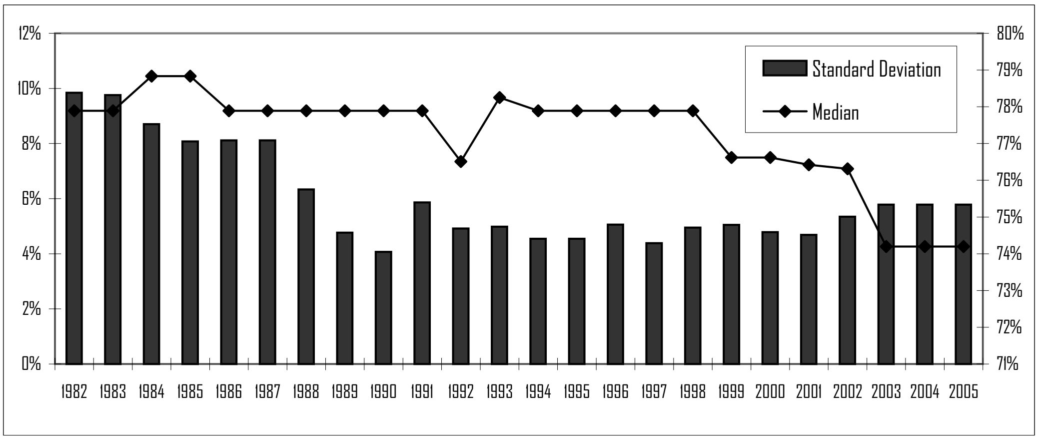

Figure 11: Allowences, median and standard deviation

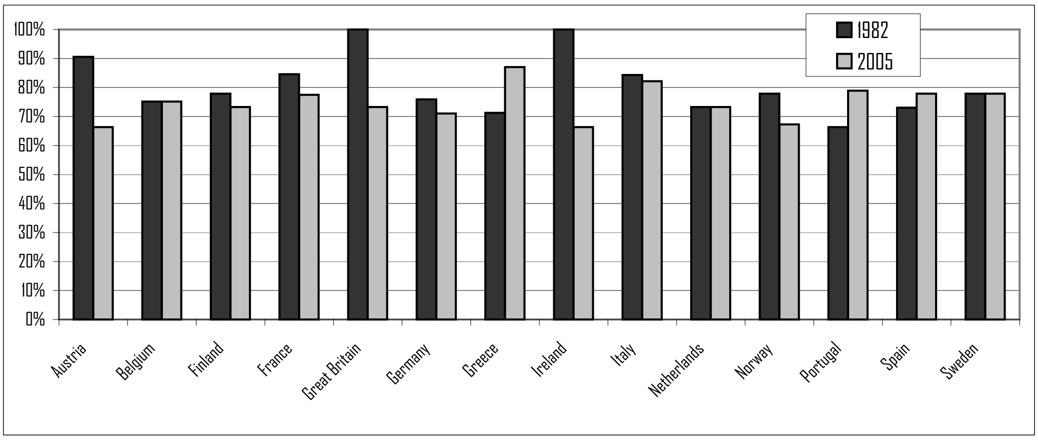

Figure 12: Allowences, country tables

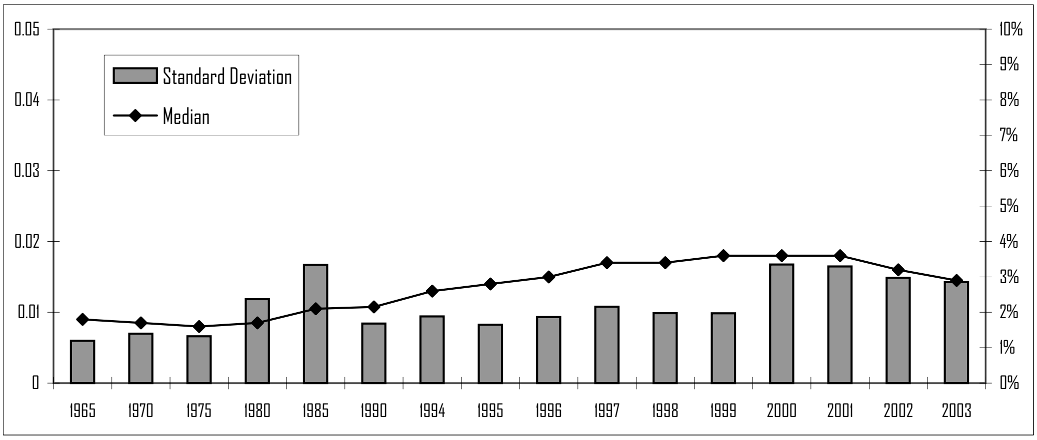

Figure 13: Corporate income tax revenue (% of GDP)

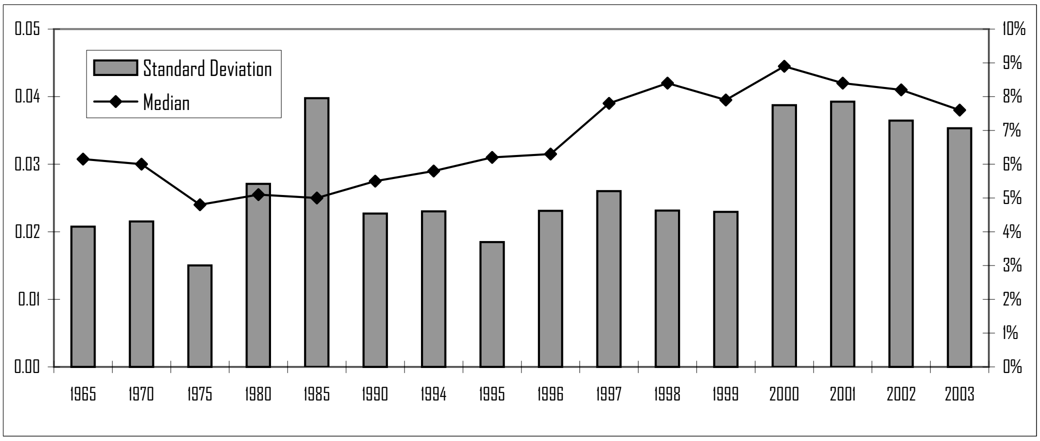

Figure 14: Corporate income tax revenue (% of total tax revenue)

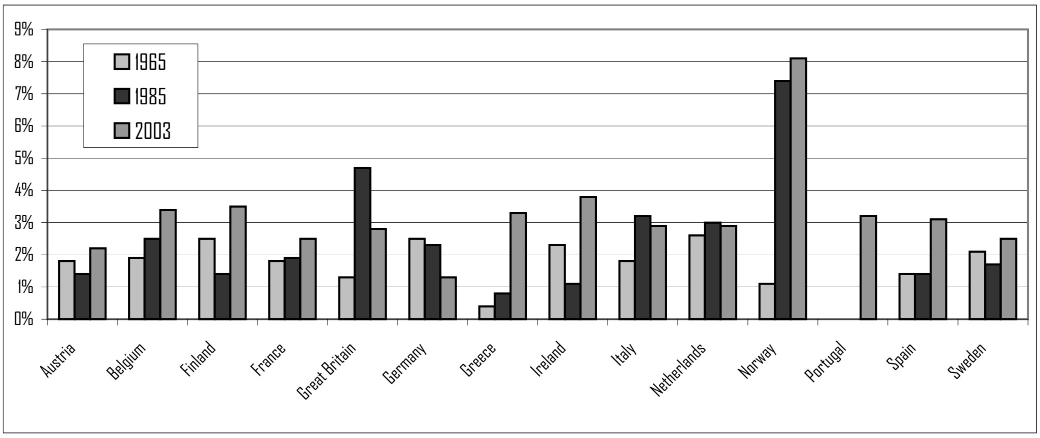

Figure 15: Corporate income tax revenue (% of GDP), country tables

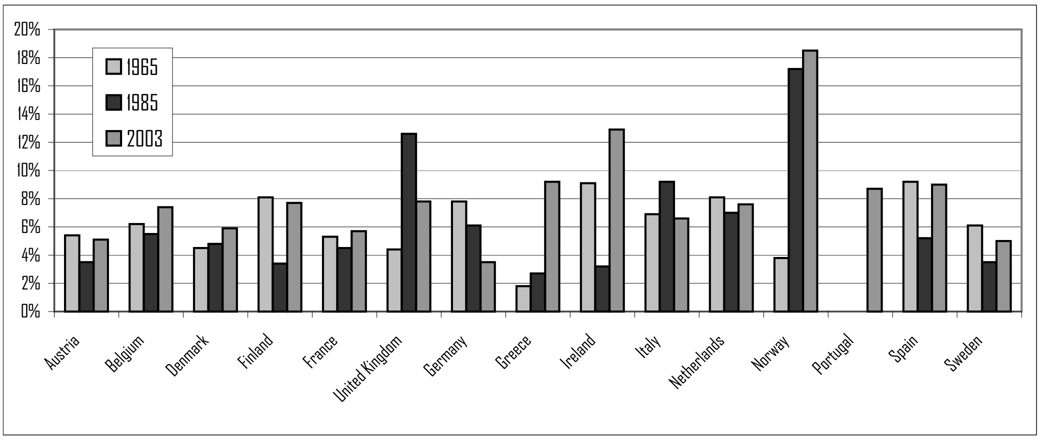

Figure 16: Corporate income tax revenue (% of total tax revenue), country tables

Determination of Characterising Variables		Case / Rose / Hines 1993	Altrusher / Goodspeed 2002	Redoano 2003	Devereux / Lookwood / Redoano 2004
Socio demographic characteristics	population that lives in urban area			x	x
	population density	x		x	
	proportion of the population that is at least 65	x		x	x
	proportion of the population that is below 14			x	x
	proportion of the population that is between 5 - 17	x			
	proportion of population that is black	x			
Economic variables	real per capita income	x			
	income squared	x			
	real per capital total federal grants to state and local governments	x			
	GDP per capita		x	x	
	total government spending as a proportion to GDP		x	x	x
	lagged value of the personal tax measure		x		
	tax revenue as a proportion to GDP			x	
	sum of FDI inflows and outflows as a proportion to GDP (openness)			x	x
	county size			x	x
	staturtory tax rate			x	
	income tax rate			x	x
	tax wedge				
Political variables	left right government dummy			x	
	election year dummy			x	

Figure 17: Summary of explainatory variables in base studies

Country	Neighbors
Austria	Germany
	Italy
Belgium	France
	Germany
	Netherlands
	United Kingdom
Finland	Norway
	Sweden
France	Belgium
	Italy
	Spain
	Germany
	United Kingdom
Germany	Austria
	Belgium
	France
	Netherlands
	Sweden
Greece	Italy

Country	Neighbors
Ireland	United Kingdom
Italy	Austria
	France
	Greece
Netherlands	Belgium
	Germany
	United Kingdom
Norway	Finland
	Sweden
Portugal	Spain
Spain	France
	Portugal
Sweden	Finland
	Germany
	Norway
United Kingdom	Belgium
	France
	Netherlands
	Ireland

Figure 18: Table of geographical weights