Is there evidence of strategic corporate tax interaction among EU countries?

Fernando Ruiz and Marcel Gerard

Catholic University of Mons (FUCaM)

2008

Is there evidence of strategic corporate tax interaction among EU countries?

Fernando M. M. Ruiz[*][†] and Marcel Gerard[‡]

Louvain School of Management and FUCaM

Belgium

16 July 2008

Abstract

In this paper we empirically investigate whether EU countries set their corporate tax interdependently and, at the same time, we examine which space may be relevant in the construction of this association. Our findings indicate the presence of tax interdependency among the EU-15 in statutory and effective corporate taxes based on the tax codes. Moreover, corporate taxes in the EU-15 seem to suffer from common external shocks.

Keywords: Tax mimicking, tax competition, spatial panel.

JEL: H73, H70.

[*]Address: Chaussée de Binche 151, B-7000 – Mons (Belgium). Tel.: +32-65-323448; fax: +32-65-323365; e-mail: fernando.ruiz@fucam.ac.be

[†]I thank Sonia Paty, Hubert Jayet, Paul Elhorst and participants at the 5th Spatial Econometric and Statistics Workshop and 5th Journées d'économie publique Louis-André Gérard-Varet for valuable comments. This paper was completed while I was at the EHESS - GREQAM Marseille. That stay was possible thanks to a grant of the Belgian FNRS and the IAP 5/26.

[‡]Marcel Gerard is also affiliated with the University of Louvain, CESifo and IDEP.

Is there evidence of strategic corporate tax interaction among EU countries?

16 July 2008

Abstract

In this paper we empirically investigate whether EU countries set their corporate tax interdependently and, at the same time, we examine which space may be relevant in the construction of this association. Our findings indicate the presence of tax interdependency among the EU-15 in statutory and effective corporate taxes based on the tax codes. Moreover, corporate taxes in the EU-15 seem to suffer from common external shocks.

Keywords: Tax mimicking, tax competition, spatial panel.

JEL: H73, H70.

One important contribution in economic theory in the last years has been the study of strategic tax interactions among jurisdictions. Those theoretical processes are assumed to be due to yardstick competition or tax competition. On the one hand, yardstick competition explains that voters may evaluate the decision of their policy makers by comparing similar policies in neighboring regions. Under those circumstances, governments may be forced to emulate each other leading to uniformity in taxes. On the other hand, tax competition argues that in open economies "independent governments engage in wasteful competition for scarce capital through reductions in tax rates and public expenditure level", Wilson (1999)[54]. Nevertheless, both models arrive to the same conclusions: taxes depend on own countries characteristics and taxes in neighboring countries.

In this article, we examine whether those tax interactions are present in the EU-15 using different effective tax rates on corporations. Moreover, we analyze which space might be relevant in the determination of tax reaction functions across countries.

Our results indicate that strategic interactions among European countries are rather scarce. Two notable exceptions are the effective taxes based on the tax codes and the statutory corporate taxes. Their spatial interaction mainly support the idea of tax competition, given that, as Redoano (2003)[42] points out, "Corporate taxes mainly affect firms' location and investments but only a minority of voters, therefore any strategic behavior by governments should be related to tax competition to attract tax base rather than yardstick competition to attract voters". Furthermore, we observe that the EU-15 acts as a block suffering common external shocks.

There exists a widespread belief among politicians and many academic researchers that an increasing openness or globalization of the economies is leading countries to a race to the bottom in corporate taxation (European Commission, 2001[19]).

Several papers have confronted that question with available data. Slemrod (2004)[49] found that "measures of openness are negatively associated with statutory corporate rates, although not with revenues collected as a fraction of GDP". Other studies support those findings, though some others arrive to different results. Among the supporters of a negative association, we also find: Rodrik (1997)[45] who shows that taxes on capital for OECD countries during the period 1965-91 respond negatively to increases in openness, while taxes on labor respond positively; Swank and Steinmo (2002)[53] who show that capital mobility and trade are associated with cuts in statutory corporate tax rates; and Winner (2005)[55] who finds that capital mobility exerts a negative impact on capital tax burden, and a positive one on labor tax burden. On the opposite side, we have studies such as Quinn (1997)[41] finding significant evidence that capital account liberalization is positively associated with corporate taxation. Nevertheless, some other works observe that globalization is unrelated with corporate taxation (Garrett, 1998)[28].

The main drawback of those kind of studies in an economic area such as the European Union, where restrictions to the movement of capital have been eliminated, is the interpretation of the parameter "openness". This term cannot carry any meaning in a by definition open internal market economy. For that reason, instead of analyzing a consequence (or a derived result) of a tax competition model, we will examine the real grounds over which that model is based, i.e. whether governments in setting their corporate tax rate consider taxes in neighboring countries.

As a direct way to validate the hypothesis, models of yardstick and tax competition usually propose an equilibrium level, which can be empirically tested through tax reaction functions (see for example Brueckner (2003)[13]). That same line will be followed in the empirical estimation of this article. However, one point must be clear at this stage. The presence of those interactions does not tell us the direction taxes take. They only indicate that governments consider in their decision process the policies of their neighbors or competing countries. They do not provide any information of a race to the bottom or stabilization around another stationary level.

There exists a small recent literature attempting to estimate tax reaction functions of national governments competing against other national govern-

	D., L. and R. (2002) EATR	R. (2003) Corporate Stat. tax	A. and G. (2002) SGDP	B., G. and K. (2002) SGDP
Inv. dist. weight	Yes (+)	Yes (+)	Yes (+)	---
GDP weight	Yes (+)	Yes (+)	---	---
GDP per capita weight	---	No	---	---
OECD equal weight	---	---	---	Yes (+)

Figure 1: Are there strategic interactions among countries?

ments. The results of that literature are summarized in Figure 1, highlighting the presence of strategic interactions among countries. Among those papers, we have the work of Devereux, Lockwood and Redoano (2002)[22], finding evidence that OECD countries with relatively high effective average tax rates (EATR) tend to respond more strongly to tax rates in other countries. On the other hand, they only find weak evidence that countries compete over effective marginal tax rates (EMTR). In other words, their study finds positive reaction functions using EATRs and considering as neighbors those countries close in geographical distance and GDP. Similarly, Redoano (2003)[42] finds evidence that tax competition mainly occurs with geographically close countries, showing the same positive effects as the previous study, using statutory tax rates, but no evidence of strategic interactions when considering GDP per capita. Altshuler and Goodspeed (2002)[1], obtain a positive Nash reaction function for European countries using corporate tax revenue over GDP (SGDP) and countries close in geographical distance, but no reaction with respect to labor taxes. They also suggest that over time, European countries have competed more intensely with the US in corporate taxes, but less intensely among themselves. Finally, Besley, Griffith and Klemm (2001)[9], observe that taxes on mobile factors in OECD countries react more than taxes on less mobile factors considering corporate tax revenue over GDP (SGDP) and giving equal weight to all countries.

Several other works examine strategic interactions within a country. Without being exhaustive, a summary of papers for the US is the following: Ladd

(1992)[34] shows that tax mimicking appears among neighboring counties; Kelejian and Robinson (1993)[33] indicate that public expenditure positively influence neighbors considering a large number of counties; Anderson and Wassmer (1995)[2] find an emulation effect of property tax abatement offers among municipalities in metropolitan Detroit; Brueckner (1998)[12] provides evidence on strategic interaction among local governments in California; Brueckner and Saavedra (2001)[14] investigate local property tax competition in the Boston metropolitan area; Case, Rosen and Hines (1993)[17] observe that states' expenditures depend on the spending of neighboring states; Figlio, Kolpin and Reid (1999)[27] explore the degree to which states simultaneously set welfare benefits; Besley and Case (1995)[8] provide evidence of yardstick competition among states; Rork (2003)[46] disaggregates Besley and Case tax measure into its individual components, and observes how those taxes mimic neighboring states; Esteller-Moré and Solé-Ollé (2001)[25] find vertical interdependence of taxes. For other countries we also have a large empirical literature: Brett and Pinkse (2000)[11] find some evidence that municipalities in the province of British Columbia (Canada) react to increases in business property tax rates of their neighbors, although they argue against the presence of competition for capital; Hayashi and Boadway (2001)[29] observe significant vertical and horizontal tax interactions among Canadian provinces; Revelli (2001)[43] tests for mimicky in local tax setting in English districts; Revelli (2003)[44] explores horizontal and vertical fiscal interactions at the level of English local governments; Bordignon, Cerniglia and Revelli (2003)[10] test for fiscal interaction arising from yardstick competition among Italian local governments; Heyndels and Vuchelen (1998)[30] present evidence of tax mimicking among Belgian municipalities; Buettner (2001)[16] identifies strategic business tax interactions among German local jurisdictions; Solé-Ollé (2003)[50] confirms the presence of tax mimicking behavior among Spanish municipalities; Feld and Reulier (2005)[26] provide evidence on strategic tax setting by Swiss cantonal governments; Dubois, Leprince and Paty (2005)[23], Paty (2006)[40], Jayet, Paty and Pentel (2002)[31], Leprince, Paty and Reulier (2005)[36], Leprince, Madiès and Paty (2005)[35] and Charlot and Paty (2005)[18] observe strategic tax interactions among local French jurisdictions.

The rest of the paper is structured as following. In section 1, we explore the equation used to detect strategic interactions. Section 2 presents the data and Section 3 the weighting schemes. In Section 4, we estimate a spatial panel and test its structure. Finally, Section 5 summarizes our conclusions.

1 Do countries play Nash equilibrium strategies in tax rates?

The basic result of the tax competition literature states that the local capital tax rate should react to tax changes in other competing countries. The classical approach to empirically test this assumption has been to estimate tax reaction functions (see Brueckner, 2003). The reaction function tries to capture how the magnitude of a tax, a decision variable of a government, depends on taxes set on other countries. In other words, the estimating equation may be written:

$$t_i = \alpha + \beta \sum_{j \neq i} \varpi_{ij} t_j + X_i \theta + \epsilon_i \tag{1}$$

where t is the tax rate, α, β and θ vector are parameters to be estimated and ϵ is the error term. Additionally, we assign weights ϖ_{ij} indicating the possible influence of neighboring taxes in the determination of the local tax.

Some main problems arise in the estimation of equation (1), notably the endogeneity of t_j's and possible spatial error dependence (see Anselin, 1988[3]).

We discuss those issues in Appendix A.

The first term on the RHS of equation (1) is referred to as the spatially lagged dependent variable, with associated autoregressive parameter β. If the slope of the estimated reaction function is non-zero we can speak of a strategic interaction among governments. In other words, a test on the absence of any spatial dependence is a test on the joint null hypothesis $H_0 : \beta = 0$ and $\lambda = 0$, where λ measures the spatial dependence in the error term. Typically, the tests are carried out looking for one kind of dependence and assuming the other to be absent. In one word, the null hypothesis in a spatial lag test is $H_0 : \beta = 0$, conditional upon $\lambda = 0$, and similarly, a test for spatial error dependence is $H_0 : \lambda = 0$, conditional upon $\beta = 0$.

In X we add a number of explanatory variables that affect the tax level and the payoff function of the country. However, we could hardly include all benefits for the countries like reciprocity or reputation when we examine this repeated game played by sovereign states, or more simply, the fairness norm used by the decision maker. As we mention in Appendix A, the omitted variables included in the error term are likely to be spatially dependent. For example, reciprocity value is by itself a multidirectional flow, probably being stronger among those entities with closer links. Ignoring this problem may cause a positive estimate of β, while in reality there is not strategic interaction, but only spatial error dependence.

Another important problem in this kind of studies is that the spatial dependence may transcend the boundaries of the data set. This edge effect is multidirectional in the sense that values outside the sample are not only influencing those available observations, but also are influenced by those in the sample. It is clear for our problem that EU corporate taxes are influencing taxes outside the union, but at the same time, they are being influenced by those taxes. Nevertheless, we are expecting (assuming) that the effects of such actions are limited and less hurting because of the barriers imposed by the union.

2 Data

The sample is composed of 4 different effective average capital tax rates[1] plus the statutory corporate tax. The effective taxes try to summarize, in a way, the country's corporate tax system. Each of them has its pros and cons, and they are surely perfectible variables. Nevertheless, they represent examples of the four different average effective tax rates on capital presented in Ruiz and Gérard (2007)[48].

The first selected series (hereafter EATR) are the ones constructed by Devereux, Griffith and Klemm (2002)[21] available on line at www.ifs.org.uk, in Table A9, for 13 countries of the EU. A second series (hereafter BACH) were constructed following the same methodology as in Nicodème (2001)[39], as the ratio of taxes paid on gross operating profit. The sector chosen is the manufacturing enterprises for 11 countries of the EU. For the third series we work with data produced by Martinez-Mongay (2000) [38] (hereafter MM) for 15 EU countries. He calculated an effective capital income tax considering taxes on personal income from capital, taxes on corporate income and property taxes. Finally, we constructed series of corporate tax revenue expressed as percentage of GDP (hereafter SGDP) for 15 EU countries. A detailed description of how the series are constructed is given in Appendix B.

For our panel estimation of Section 4 and Section 6, we take the period 1982-2001 with EATR, 1982-2001 with the Statutory tax, 1991-2001 with BACH, 1979-2001 with MM and 1989-2001 with SGDP. As a set of control variables in Section 4, we include domestic socio-economic characteristics, which try to

[1] Those variables are used in Ruiz (2006)[47].

capture factors influencing the corporate tax rate. On the other hand, international pressures are implicitly taken into account in the design of strategic tax interactions among countries.

The first domestic explanatory variable is based in what Slemrod calls the folk theorem among tax policymakers: "all taxes have weaknesses, and the marginal social cost of the weaknesses increase with the tax system's reliance on any given tax. Therefore, revenues should be collected from a variety of taxes rather than a small number". Therefore, as an implication, if government spending increases, revenue needs to increase and corporate taxation should follow that tendency.

The second variable tries to capture the vision of many policymakers and voters, which observe the corporate taxation as an instrument for tax progressivity and redistribution. This tax, in fact, may allow a sort of resource redistribution among the population. Particularly, we use as a proxy for redistribution the fraction of population over 65 years old given that the higher their percentage, the higher the financing needs for pensions and health services.

The third variable searches to observe the size effect of a country. Several theoretical models such as Bucovetsky (1991)[15] analyze differences in the size of the competing countries, arriving to the conclusion that the larger the country the higher the tax rate it chooses.

The last variable tries to capture the effect of EU accession in the capital tax. Given that not all countries of our dataset were in the European Union at the beginning of the series, we expect that becoming a member increases the pressures of tax competition, inducing a change in the tax rate.

In a preliminary version of this paper we considered other explanatory variables such as tax on labor, capital stock and net returns to capital. Those variables were not finally retained because of a possible endogeneity problem

Variable	Description	Source
GEXP/GDP	Government final consumption expenditure divided by GDP	OECD
Po65/Po	Population +65 divided by total population	AMECO
Size	GDP divided by the sum of GDPs of the EU	AMECO
EU	Dummy variable, 1 = member of the EU	

Figure 2: Domestic socio-economic control variables.

(other variables as FDI suffer a similar drawback). We also explored political variables, for example the percentage of left party legislative seats and left party cabinet portfolios. Likewise they were dropped from the estimation because they appeared not significant.[2]

3 Weighting schemes

Uncertainty with respect to the proper specification of the spatial weights matrix is a fundamental problem in the study of strategic interactions, particularly, because we do not exactly know where international pressures come from. A potential problem of drawing inappropriate conclusions arises, as the specified weight matrix may not be the true weight matrix, or in other words, we have a problem of a priori finding the correct links of tax settings among countries (if there is one). Stetzer (1982)[52] illustrates how a misspecified weight matrix may result in inconsistent estimates and misleading inference. One potential solution may be the use of Getis-Ord statistic to endogenously detect spatial clustering. However, the use of that statistic on the small cross-sectional sample of our study does not shed additional light on the source of the spatial interaction among countries.

Although the weights imposed in (1) may seem arbitrary, we explore a variety of weighting schemes to establish which patterns of spatial interaction are

[2] A Moran's I statistic was also estimated for two years showing a few significant results. Particularly, we found some spatial autocorrelation for taxes based on the tax codes at the beginning of the sample. Results can be requested to the authors.

relevant for the capital reaction function across countries (clearly a choice of different weights is likely to result in a different estimation for β, although, in all cases, the estimated coefficient must be smaller than one because of stability issues).[3]

A panel version of model (1) is estimated using a total of seven weighting matrices, each of them row standardized such that the $\sum_{j=1}^{n} \varpi_{ij} = 1$. The weights can be separated in three categories: geographical weights (weights W-1, W-2 and W-3), economic weights (weights W-4 and W-5) and clustering weights (weights W-6 and W-7). The first weighting matrix is a distance matrix, which considers as neighboring countries those states whose capitals are within a given minimum distance (δ) required to ensure that each location has at least one neighbor. An equal weight is given to those countries within the distance-band. A second weighting scheme assigns an inverse distance weight to those countries within the distance-band explained before (i.e. $\varpi_{ij} = \frac{1/d_{ij}}{\sum_{j=1}^{n} 1/d_{ij}}$ if $d_{ij} \leq \delta$, $\varpi_{ij} = 0$ if $d_{ij} > \delta$). The third weighting matrix considers as neighbors all countries of the sample and the weights are simply the inverse distance. The fourth weights are based on economic characteristics giving to each country a weight depending on the difference of GDP (i.e. $\varpi_{ij} = \frac{\frac{1}{|GDP_i - GDP_j|}}{\sum_{j=1}^{n} \frac{1}{|GDP_i - GDP_j|}}$). This scheme provides stronger links to those countries closer in GDP. The fifth approach is similar to the weights 4 but considering GDP per capita. Weight 6 considers as neighbors those countries with similar tax systems as clustered in the Company taxation report (European Commission 2002 [20], table 1.5),[4] giving equal weight to each neighbor. Finally, weight 7 clusters countries in two groups: high statutory tax

[3] With IV estimations the spatially autoregressive parameter is unrestricted and it may result in values larger than one. That may indicate to a general misspecification of the model.

[4] The neighbors are: Belgium, Netherlands, Austria and Finland; Greece, France, Ireland and Italy; Denmark, Germany, Spain and Sweden; Luxembourg, Portugal and United Kingdom.

rates[5] and low statutory tax rates[6] in the year 2001.

4 Panel estimation

4.1 Pooled cross-section estimation without considering international pressures

Let us begin by examining a classical panel data model. We include in all cases country fixed effects to account for any unobserved individual characteristics that are not included in the regression and may explain differences in mean levels across countries. Moreover, we consider time fixed effects to control for common macro shocks, such that the errors are equicorrelated across space.[7] In next subsection we will test which form of spatial dependence prevails in the data.

Our estimating panel equation is:[8]

$$t_{i\iota} = \alpha + X_{i\iota}\theta + \epsilon_{i\iota} \tag{2}$$

where the overall error consists of:

$$\epsilon_{i\iota} = \mu_i + \lambda_\iota + \phi_{i\iota}$$

Table 2 shows the results concerning the four different effective average capital tax rates presented in Section 2 and discussed in Appendix B plus the statutory corporate tax rate. The taxes EATR and BACH can be interpreted as based on micro data, while the last two (MM and SGDP) as based on macro

[5] High statutory tax countries in 2001 are: Belgium, Italy, Greece, Austria, Spain, France, Netherlands and Portugal.

[6] Low statutory tax rate countries in the year 2001 are: Ireland, Sweden, Finland, Luxembourg, UK, Denmark and Germany.

[7] Although this form of error component does not allow for distance decay effects.

[8] **In this paper time is represented by ι (iota).**

Table 1: Mean and S.D. of effective average tax rates.

Effective capital tax	Mean	S.D.
EATR	29,2733	9,3840
Statutory Tax	39,6769	12,6907
BACH	14,6813	4,5863
MM	20,7664	6,3655
SGDP	2,9639	1,4626

data. The most striking feature of the series is the different path they follow across time (as presented in Ruiz (2006)[47] and explained in Sorensen (2006)[51]), suggesting that the effects of the explanatory variables may change through the estimations.

Slemrod (2004) observes no association of the government expenditure - GDP ratio with the corporate statutory rate and only a weak positive association with the corporate tax revenue over GDP. In contrast, we find strong negative relations between that ratio of government expenditures and the statutory tax and micro effective tax rates. That result may suggest that governments finance their increasing expenditures from other sources of revenue. Observing macro taxes, we also obtain negative coefficients, although they appear not significant.

Examining next the variable of population over 65 years old, we can see an element of redistribution in the society. Particularly, in the Statutory tax, EATR and MM regressions we can clearly observe that the larger the phenomenon of ageing population, the higher the capital tax.

The size variable in Statutory tax and EATR clearly supports the idea that a large country may face a lower elasticity of capital to the tax rate, and therefore, it may maintain a higher tax. For the rest of the estimations this coefficient is not significant.

Finally, the dummy variable for the EU membership shows negative coefficients in the Statutory tax and EATR regressions, suggesting an increase in competition when countries join the union. However, observing macro taxes we

Table 2: Regressions without considering strategic interactions.

	EATR	**St. Tax**	**BACH**	**MM**	**SGDP**
GEXP/GDP	-1,6678	-1,7966	-1,2462	-0,1278	-0,1074
	(0,00)[a]	(0,00)[a]	(0,00)[a]	(0,24)	(0,07)
Po65/Po	2,4292	5,2733	0,5307	1,5526	0,0318
	(0,00)[a]	(0,00)[a]	(0,30)	(0,00)[a]	(0,74)
Size	0,7366	1,6507	-0,2864	0,2485	0,0691
	(0,01)[a]	(0,00)[a]	(0,39)	(0,11)	(0,20)
EU	-4,3954	-5,9896	1,0266	3,0178	0,7037
	(0,00)[a]	(0,00)[a]	(0,32)	(0,00)[a]	(0,00)[a]
C	27,5275	-6,1657	35,2197	-2,8920	3,6290
	(0,00)[a]	(0,45)	(0,00)[a]	(0,33)	(0,04)[b]
Observations	260	260	121	345	195
R^2	0,8666	0,8868	0,8307	0,8919	0,8794
Log likelihood	-688,7319	-745,7751	-248,0111	-743,7677	-144,1295

p-values are in parentheses

[a] Significant at 1% level.

[b] Significant at 5% level.

obtain a positive influence, reflecting a probable growth in the corporate income tax base.

One open question to be analyzed in next sections is whether and how a corporate tax regime in one country reacts to changes in neighboring countries.

4.2 Testing spatial dependencies

4.2.1 Spatial specification search

In our discussion of Appendix A we argue that spatial dependencies may be due to spatially associated dependent variables or omitted variables, themselves spatially associated, included in the error term. This section will try to unravel that question; although, as it will be clear below, the different effective tax rates and weighting matrices conduce to a wide range of results.

We explore the source of spatial dependency through the lagrange multiplier test (LM), which has the absence of spatial correlation as the null hypothesis.

One important point to highlight here is that the alternative hypothesis does not differentiate between positive or negative spatial dependencies. Anselin, Le Gallo and Jayet (2007)[4] provide the generalized formulas for the LM tests in pooled models. The LM-Lag refers to the spatial lag model as the alternative hypothesis and its extended form is:

$$LM_L = \frac{\left[e'\left(I_T \otimes W\right)t/\left(e'e/NT\right)\right]^2}{\left[\left(W\widehat{y}\right)' M \left(W\widehat{y}\right)/\sigma^2\right] + Ttr\left(W^2 + W'W\right)}$$

where e is a vector of regression residuals, $W\widehat{y} = \left(I_T \otimes W\right) X\widehat{\theta}$, and $M = I_{NT} - X\left(X'X\right)^{-1} X'$. Similarly, the LM-Error has the spatial error model as the alternative hypothesis and its statistic becomes:

$$LM_E = \frac{\left[e'\left(I_T \otimes W\right)e/\left(e'e/NT\right)\right]^2}{Ttr\left(W^2 + W'W\right)}$$

Both one-directional tests are distributed as χ^2 with one degree of freedom.

We present the results of the LM tests in Figure 3. There each lag and error LM test is estimated considering a panel without fixed effects (NE), with country fixed effects (CE), and with time and country fixed effects (T&C E). As expected, the outcomes of the tests point toward different directions. Selecting between a lag and an error model is not free from ambiguity, given that a result indicating a lag model with one tax may suggest an error specification with a different tax. For example, looking at row W-2 with fixed effects (T&C E) we observe the spatial lag as the correct specification considering the EATR, although we can reject the null hypothesis in favor of the spatial error specification considering the MM.

One simple rule that can help us in our decision, based on common sense, is to count the values rejecting the null hypothesis. From the 105 different alternatives we observe that 59 times we can reject the null hypothesis against the spatial lag model and only 49 times against the spatial error model. This provides some evidence that the spatial lag model may imply the correct form of spatial association. Moreover, it gives an indication that the theoretical results suggesting strategic tax interactions among countries may be supported in the data, although it does not tell us the direction of such interaction.

4.2.2 Fixed effects tests

Our second search concerns the selection of a panel structure with country effects, time and country effects or none of them. In Section 4.1 we have assumed time fixed effects to allow errors equicorrelated across space. That option can be justified with a F-test or a likelihood ratio (LR) test. For instance, testing for the existence of time effects and allowing for individual effects, i.e.

$$H_0 : \lambda_1 = ... = \lambda_{T-1} = 0 \text{ allowing } \mu \neq 0; i = 1, ..., (N-1)$$

we can perform a F-test, such that

$$F = \frac{(RRSS - URSS) / (T-1)}{URSS / (N-1)(T-1) - K} \overset{H_0}{\sim} F_{(T-1),(N-1)(T-1)-K}$$

where the unrestricted residual sums of squares (URSS) is obtained from (2) and the restricted residual sums of squares (RRSS) is calculated from an expression similar to (2) without time effects. Similarly, a test for the joint significance for time and country effects considers the RRSS without dummy variables and $N+T-2$ degrees of freedom for the numerator. The first row in Figure 4 shows the rejection of the null hypothesis of redundant time effects in four of the five cases, and redundant country and time effects in the five taxes considered in our panel model of Section 4.1.

With the inclusion of a spatially lagged dependent variable the tests can be

			EATR	St. Tax	BACH	MM	SGDP
W - 1	N.E.	LM-Lag	7,7784*	26,5626*	0,0160	0,0789	1,0734
		LM-Error	4,0436**	17,1984*	0,2829	0,0496	1,9300
	C.E.	LM-Lag	51,6254*	59,8164*	0,4863	1,9381	0,0047
		LM-Error	28,2248*	43,4783*	1,6131	0,8418	8,7302*
	T&C E.	LM-Lag	20,7484*	14,9843*	2,0232	0,0012	6,2994**
		LM-Error	4,7651**	1,8527	6,5556**	5,8004**	11,1782*
W - 2	N.E.	LM-Lag	9,1962*	27,2962*	0,0213	0,0149	0,0026
		LM-Error	6,9931*	22,4969*	0,1148	0,0466	0,3145
	C.E.	LM-Lag	44,7983*	53,4406*	0,4101	1,0081	0,0028
		LM-Error	25,5680*	42,8033*	1,5223	1,6790	7,5516*
	T&C E.	LM-Lag	14,2523*	11,0884*	2,0927	0,1422	5,9042**
		LM-Error	2,4419	0,9367	6,6845*	7,6344*	10,0764*
W - 3	N.E.	LM-Lag	14,2670*	39,6189*	6,9694*	0,8030	1,3760
		LM-Error	9,5237*	33,8391*	2,7742	4,3420**	0,0893
	C.E.	LM-Lag	41,2764*	70,2198*	5,6041**	0,0005	4,9113**
		LM-Error	13,6334*	37,5754*	0,1283	1,5190	0,2710
	T&C E.	LM-Lag	0,0575	0,0407	4,3162**	8,1768*	6,1798**
		LM-Error	2,0951	1,9192	6,3547**	15,3133*	6,4631**
W - 4	N.E.	LM-Lag	0,1664	2,5952	4,9181**	0,0423	2,4823
		LM-Error	0,2074	0,8615	0,9811	3,6927	0,4385
	C.E.	LM-Lag	11,5971*	21,6053*	5,2529**	11,1049*	33,4544*
		LM-Error	1,9803	7,6755*	1,0104	6,3621**	11,6181*
	T&C E.	LM-Lag	3,9415**	6,8596*	1,1225	3,6921	9,5881*
		LM-Error	0,1069	2,5310	0,5885	0,8401	7,1380*
W - 5	N.E.	LM-Lag	24,1680*	35,0226*	2,4203	22,1748*	0,6602
		LM-Error	39,2263*	58,3606*	1,7745	15,9925*	1,5281
	C.E.	LM-Lag	21,1603*	59,1255*	4,0171**	15,7780*	6,2864**
		LM-Error	13,2263*	45,0172*	0,2577	9,6266*	0,8907
	T&C E.	LM-Lag	4,1740**	0,5037	7,2336*	6,4699**	0,8669
		LM-Error	1,6891	0,0668	6,2358**	2,0920	0,2686
W - 6	N.E.	LM-Lag	0,0881	0,0665	0,0233	4,8057**	6,8890*
		LM-Error	1,9919	0,2974	0,6529	5,7915**	0,9637
	C.E.	LM-Lag	5,6479**	17,6268*	2,3013	2,9302	1,0015
		LM-Error	0,2608	4,9302**	0,1881	5,9713**	1,5950
	T&C E.	LM-Lag	8,7498*	0,1547	2,7511	12,8992*	2,7452
		LM-Error	9,8436*	2,9678	3,8295	14,7853*	3,7400
W - 7	N.E.	LM-Lag	1,2340	9,9467*	5,5487**	15,6228*	0,1131
		LM-Error	8,0191*	38,3272*	3,1319	11,4129*	0,2182
	C.E.	LM-Lag	17,4800*	47,1801*	3,6298	0,5177	2,1620
		LM-Error	8,4906*	23,0858*	0,0378	0,6336	2,1972
	T&C E.	LM-Lag	8,7572*	1,5991	5,1659**	9,9840*	8,3127*
		LM-Error	3,4807	1,5857	7,9802*	7,8787*	10,3561*

* Significant at 1% level
** Significant at 5% level

Figure 3: LM tests.

carried out in similar manner, as proposed by Elhorst (2003)[24]. Nevertheless, for spatial panels estimated by maximum likelihood, the F-test is only asymptotically valid. For that reason, a LR test may provide a more reliable indicator for model selection. Indeed, the LR test is unbiased and consistent. It requires the computation of the log likelihood

$$l = -\frac{NT}{2}\left(1 + \log(2\pi + \log\left(\frac{e'e}{NT}\right)\right)$$

As in the F-test, the LR test is conducted by looking at the difference between the log likelihood values of the restricted (l_R) and unrestricted (l_U) versions of the equation. Further, $-2\,(l_R - l_U)$ has a χ^2 distribution with a number of degrees of freedom equal to the quantity of parameters specified in H_0.

The rest of rows in Figure 4 present the result for the different weighting schemes. They indicate a generalized rejection of the null hypotheses, suggesting the inclusion of time and country dummy variables as correct characteristics.[9] On the other hand, this is not somewhat unexpected. The effective average tax rates used in this study are likely to suffer from common shocks of the European Union. For instance, a synchronization of the business cycle in Europe reported by Artis and Zhang (1999)[5] is simultaneously affecting the effective tax BACH, MM and SGDP (although it does not influence the Statutory tax and EATR). It is also consistent with the idea that changes in foreign taxes not included in the regression, are simultaneously affecting the whole EU-15.

[9] Observe in Figure 3 that the inclusion of time and country fixed effects also respect the advantage towards a spatial lag model.

Redundant fixed effects tests							
			EATR	**St. Tax**	**BACH**	**MM**	**SGDP**
No spatial effects	F-test	T.E.	7,0157*	11,3425*	2,0412**	0,8620	1,9306**
		C&T E.	33,8124*	33,9480*	14,4868*	46,2682*	36,2372*
	LR-test	T.E.	121,4008*	175,2418*	23,3270*	20,8763	25,7668*
		C&T E.	451,5798*	452,4375*	168,2871*	644,6621*	372,2142*
W-1	F-test	T.E.	3,8321*	6,3787*	2,2551**	0,7093	2,8883*
		C&T E.	34,9876*	30,1410*	14,7317*	45,9380*	37,8536*
	LR-test	T.E.	86,3201*	128,9189*	25,0748**	18,3652	32,6143*
		C&T E.	459,5533*	436,7812*	170,5732*	644,5475*	377,3619*
W-2	F-test	T.E.	3,9695*	6,6106*	2,2975**	0,7890	2,7537*
		C&T E.	33,3023*	29,0714*	14,7799*	46,0054*	38,1044*
	LR-test	T.E.	88,5024*	132,3047*	25,2433**	19,7437	32,3532*
		C&T E.	452,1032*	431,2737*	170,6458*	644,8275*	378,8001*
W-3	F-test	T.E.	3,4633*	5,0897*	2,9328*	2,5102*	3,8751*
		C&T E.	30,2502*	26,7380*	15,4585*	51,8630*	42,1226*
	LR-test	T.E.	82,6469*	115,1117*	26,1199*	33,4615**	34,5586*
		C&T E.	437,1854*	418,0870*	170,3299*	656,2271*	384,1624*
W-4	F-test	T.E.	6,2972*	9,6908*	1,6142	0,5359	0,1598
		C&T E.	34,4371*	34,9416*	13,5820*	46,8550*	37,8383*
	LR-test	T.E.	113,9933*	160,9797*	19,5449**	13,9622	3,9671
		C&T E.	455,188*	457,2876*	165,0197*	648,0623*	377,0939*
W-5	F-test	T.E.	5,483*	4,6754*	4,0735*	0,4454	1,3704
		C&T E.	28,5719*	24,8375*	17,8408*	42,2174*	35,9507*
	LR-test	T.E.	104,6447*	112,2770*	32,2199*	12,6879	20,3063
		C&T E.	428,0919*	409,3752*	178,4230*	626,8815*	372,5250*
W-6	F-test	T.E.	7,2781*	8,7109*	2,2000**	1,6406	2,1533**
		C&T E.	35,5651*	33,6631*	15,0345*	48,4836*	35,0705*
	LR-test	T.E.	124,5762*	154,5864*	24,3393**	32,6835	27,7587**
		C&T E.	460,5863*	452,5141*	171,6561*	654,8572*	369,4713*
W-7	F-test	T.E.	6,8184*	6,6653*	2,7563*	1,8026	4,0094*
		C&T E.	36,9585*	32,3042*	15,0313*	47,2235*	42,1788*
	LR-test	T.E.	117,9873*	133,8569*	27,4561*	34,8834**	39,4286*
		C&T E.	464,5468*	445,7965*	170,9009*	647,8371*	387,8648*

* Significant at 1% level
** Significant at 5% level

Figure 4: F and LR tests.

4.3 Pooled cross-section estimation considering international pressures

4.3.1 Maximum likelihood methods

In previous subsections we have defined the spatially lagged panel with time and country fixed effects as the appropriate structure for the present study. Accordingly, our estimating equation is:

$$t_{i\iota} = \alpha + \beta \sum_{j \neq i} \varpi_{ij} t_{j,\iota} + X_{i\iota}\theta + \epsilon_{i\iota}$$

and the overall error structure consists of:

$$\epsilon_{i\iota} = \mu_i + \lambda_\iota + \phi_{i\iota}$$

The reduced form of this equation is estimated using maximum likelihood methods, in the Matlab package developed by Elhorst.

The results are presented in Appendix C. The first column in Figure 5 and 6 repeats the results provided in Table 2. Those numbers are included to allow an easy comparison and to show consistency among the diverse estimations. The discussion of our explanatory variables is already provided in Section 4.1, and, as we can see, their effects do not vary across the diverse spatial associations. On the other hand, the parameter β is the most important estimated coefficient in the present study and represents the level of interdependence or competitive pressures countries face when setting the tax.

The tables show a rather conflicting evidence of tax interdependency. Observing the results for the Statutory tax and the EATR data with minimum distance weighting matrices, we do find evidence of strategic interactions. As explained in Ruiz and Gérard (2007)[48] the EATR series are constructed taking a limited number of provisions of the tax codes. Therefore, the results may suggest that countries are mimicking taxes and tax codes main reforms of their close neighbors. Those results were also found by Devereux, Lockwood and Redoano (2002) and by Redoano (2003). Considering next economic and cluster weights, we obtain negative coefficients. It suggests that countries close in GDP or another a priori form of tax clustering have reacted dissimilarly to changes in taxes of their neighbors. Particularly with economic weights, this result is in some degree surprising, because a second finding of Devereux, Lockwood and Redoano (2002) and Redoano (2003) is that the EATR and the Statutory tax in a country is positively associated to taxes of its economic neighbors.

In BACH data we observe a different pattern. For distance weights, we do not find evidence of proper strategic interactions. If there is such interaction, the results suggest that this is negative, showing a chess board pattern in the data. In particular, W-3 shows a significant negative value, which is supported by the more conservative LM-Lag test of Figure 3. For economic and cluster weights the outcomes are similar, indicating an absence or negative interaction. In W-5 and W-7 we find negative βs, which correspond with the LM-Lag test of Figure 3.

There also appears some evidence of negative strategic interactions considering distance weights W-3 for MM series. If we examine at the same time our second macro tax SGDP, we see negative significant βs with distance weights too. This clearly indicates that macro taxes are not spatially interdependent between geographical neighbors in the expected way. This again contradicts one previous finding obtained by Altshuler and Goodspeed (2002) who show a positive association using SGDP series and inverse distance weights. Observing macro taxes with economic weights, the results indicate some positive associations, particularly with MM taxes, although the more conservative LM-Lag test is not significant for W-4 and only slightly significant for W-5. Additionally, with SGDP taxes we cannot argue in favor of positive interactions because of the way the series are constructed (the positive interactions may only reflect an association of GDP and not of effective taxes). Finally, examining clustering weights and macro taxes we can only conclude in a direction of negative spatial associations.

Summing up, our findings indicate a probable mimicking strategy of statutory taxes and main tax code reforms between close geographical neighbors. However, considering other effective tax burdens, countries in the European Union do not seem to accommodate their taxes in a sort of strategic interaction or tax competition. In addition, all effective taxes probably suffer from common external shocks as indicated by the presence of time fixed effects. In other words, the results can be interpreted as representing an EU-15 acting like a block, reacting to common shocks, and interacting in a limited form between close geographical neighbors.

4.3.2 Instrumental variables procedure

For the sake completeness and illustration, this subsection will try to reproduce the results obtained above in the EATR and Statutory tax using instrumental variables or a two stage least squares procedure. Time and country fixed effects are again considered in the estimation. It is worth mentioning that previous studies analyzing tax interaction among countries have followed this approach.

The instrumental variable estimation involves a preliminary least squares regression of $W\tau_t$ on a set of instruments. Kelejian and Robinson (1993)[33] suggest WX_t as a set of instruments in addition to the exogenous variables X_t (which are always included as instruments). This choice of instruments follows from (4), where $(I-\beta W)^{-1}X\theta$ can be expanded in $X\theta+\beta WX\theta+\beta^2W^2X\theta+...$.

Figure 7 in Appendix C presents the results of this method. Although we will not examine each estimation in detail, we can observe a similar conflicting evidence of strategic interactions. In general, the estimated coefficients conserve the signs of the panel model without spatial effects. When the estimated spatially autoregressive parameter turns out to be significant, it normally preserves the signs found by maximum likelihood. Particularly, we find again positive βs using minimum distance weights in the EATR and Statutory tax. One main problem for preserving signs is the explosive pattern the spatial parameter shows in a number of estimations; and that occurs in several occasions. There appear $\beta\text{s} > |1|$ in EATR W-3 and Statutory tax W-3, W-4, W-5 and W-7. We have already mentioned that characteristic as the main drawback of this approach. The spatially autoregressive parameter is unrestricted and, as seen in the results, it can produce values larger than one which indicate an unacceptable explosive spatial association.

5 Conclusions

The estimations considering a classical search for strategic interactions, conclude in favor of a limited mimicking between close neighboring countries using Statutory and EATRs, but an absence of interdependency considering other measures of capital taxation. As explained in Ruiz and Gérard (2007)[48], EATRs are constructed taking into account a limited number of provisions of the tax codes. That may imply countries are mimicking tax codes main reforms of their close neighbors, but at the time of considering tax burdens effectively paid and supported by enterprises, national states still differ by large, not interacting between themselves. Additionally, all effective taxes in the EU-15 are likely suffering from common external shocks, suggesting that the countries constitute a block reacting to general external factors.

	EATR	St. Tax	BACH	MM	SGDP
Distance weight	Yes (+)	Yes(+)	No	No	Yes (-)
Economic weight	Yes (-)	Yes(-)	Yes (-)	Yes (+)	–
Cluster	Yes (-)	No	No	Yes (-)	No
Statutory cluster	Yes(-)	No	Yes (-)	Yes (-)	Yes (-)

Table 3: Summary of strategic interactions.

In Table 3 we summarize the different cases examined in the first part of this paper, showing when β is significant and the sign of its coefficient in that case. The table can directly be compared with Figure 1 of the introduction, which summarized previous results of the literature. Nevertheless, those previous studies have used instrumental variables procedures, which can derive in explosive spatial associations and certain instability in the coefficients when the correct instruments are not available.

References

[1] R. Altshuler and T. Goodspeed. Follow the leader? Evidence on European and US tax competition. *mimeo*, 2002.

[2] J. Anderson and R. Wassmer. The decision to bid for business: Municipal behavior in granting property tax abatements. *Regional Science and Urban Economics*, 25:739–757, 1995.

[3] L. Anselin. *Spatial Econometrics: Methods and Models*. Kluwer Academic Publishers, 1988.

[4] L. Anselin, J. Le Gallo, and H. Jayet. *Spatial Panel Econometrics*, chapter 18.

[5] M. Artis and W. Zhang. Further evidence on the international business cycle and the ERM: Is there a European business cycle? *Oxford Economic Papers*, 51:120–131, 1999.

[6] J. Ashworth and B. Heyndels. The evolution of national tax structures in view of the EMU. In H. Ooghe, F. Heylen, R. Vennet, and J. Vermaut, editors, *The Economic and Business Consequences of the EMU - A Challenge for Governments, Financial Institutions and Firms*, pages 155–180. Kluwer Academic Publishers, 2000.

[7] J. Ashworth and B. Heyndels. Political fragmentation and the evolution of national tax structures in the OECD. *International Tax and Public Finance*, 8 (3):377–393, 2001.

[8] T. Besley and A. Case. Incumbent behavior: Vote-seeking, tax-setting and yardstick competition. *The American Economic Review*, 85(1):25–45, 1995.

[9] T. Besley, R. Griffith, and A. Klemm. Empirical evidence on fiscal interdependence in OECD countries. *Mimeograph*, 2001.

[10] M. Bordignon, F. Cerniglia, and F. Revelli. In search of yardstick competition: A spatial analysis of italian municipality property tax setting. *Journal of Urban Economics*, 54:199–217, 2003.

[11] C. Brett and J. Pinkse. The determinants of municipal tax rates of British Columbia. *Canadian Journal of Economics*, 33(3):695–714, 2000.

[12] J. Brueckner. Testing for strategic interaction among local governments: The case of growth controls. *Journal of Urban Economics*, 44(3):438–467, 1998.

[13] J. Brueckner. Strategic interaction among governments: An overview of empirical studies. *Regional Science Review*, 26:175–188, 2003.

[14] J. Brueckner and L. Saavedra. Do local governments engage in strategic property-tax competition? *National Tax Journal*, 54:203–229, 2001.

[15] S. Bucovetsky. Asymmetric tax competition. *Journal of Urban Economics*, 30(2):167–81, 1991.

[16] T. Buettner. Local business taxation and competition for capital: The choice of the tax rate. *Regional Science and Urban Economics*, 31:215–245, 2001.

[17] A. Case, H. Rosen, and J. Hines. Budget spillovers and fiscal policy interdependence. *Journal of Public Economics*, 52(3):285–307, 1993.

[18] S. Charlot and S. Paty. The french local tax setting: Do interactions and agglomeration forces matter? *CESAER Working Paper*, 11, 2005.

[19] European Commission. Company taxation in the internal market. Technical Report 582, European Commission, 2001.

[20] European Commission. Structures of the taxation systems in the European Union. Technical report, European Commission, 2003.

[21] M. Devereux, R. Griffith, and A. Klemm. Corporate income tax reforms and international tax competition. *Economic Policy*, 35:450–495, 2002.

[22] M. Devereux, B. Lockwood, and M. Redoano. Do countries compete over corporate tax rates? *CEPR Discussion Paper*, 3400, 2002.

[23] E. Dubois, M. Leprince, and S. Paty. Les déterminants politiques des choix fiscaux locaux. *Revue de l'OFCE*, 94:317–349, 2005.

[24] P. Elhorst. Specification and estimation of spatial panel data models. *International Regional Science Review*, 26 (3):244–268, 2003.

[25] A. Esteller-Moré and A. Solé-Ollé. Vertical income tax externalities and fiscal interdependence: Evidence from the US. *Regional Science and Urban Economics*, 31:247–272, 2001.

[26] L. Feld and E. Reulier. Strategic tax competition in Switzerland: Evidence from a panel of the Swiss cantons. *CESIfo Working Paper*, 1516, 2005.

[27] D. Figlio, V. Kolpin, and W. Reid. Do states play welfare games? *Journal of Urban Economics*, 46(3):437–454, 1999.

[28] G. Garrett. Global markets and national policies: Collision course or virtous cicle. *International Organization*, 52 (4):787–824, 1998.

[29] M. Hayashi and R. Boadway. An empirical analysis of intergovernmental tax interaction: The case of business income taxes in Canada. *Canadian Journal of Economics*, 34(2):481–503, 2001.

[30] B. Heyndels and J. Vuchelen. Tax mimicking among Belgian municipalities. *National Tax Journal*, 51(1):89–101, 1998.

[31] H. Jayet, S. Paty, and A. Pentel. Existe-t-il des interactions fiscales stratégiques entre les collectivités locales. *Economie et Prévision*, 154:95–105, 2002.

[32] H. Kelejian and I. Prucha. A generalized spatial two-stage least squares procedure for estimating a spatial autoregressive model with autoregressive disturbances. *Journal of Real Estate Finance and Economics*, 17(1):99–121, 1998.

[33] H. Kelejian and D. Robinson. A suggested method of estimation for spatial interdependent models with autocorrelated errors, and an application to a county expenditure model. *Papers in Regional Science*, 72(3):297–312, 1993.

[34] H. Ladd. Mimicking of local tax burdens among neighboring counties. *Public Finance Quarterly*, 20(4):450–467, 1992.

[35] M. Leprince, T. Maladiès, and S. Paty. Interactions fiscales verticales: Un test sur données départamentales. *mimeo*, 2005.

[36] M. Leprince, S. Paty, and E. Reulier. Choix d'imposition et interactions spatiales entre collectivités locales: Un test sur les départements français. *Louvain Economic Review*, 71(1):67–93, 2005.

[37] J. LeSage. Bayesian estimation of spatial autoregressive models. *International Regional Science Review*, 20:113–129, 1997.

[38] C. Martinez-Mongay. ECFIN's effective tax rates. properties and comparisons with other tax indicators. *ECFIN/593/00*, 2000.

[39] G. Nicodème. Computing effective corporate tax rates: Comparisons and results. *ECFIN E2/358/01*, 2001.

[40] S. Paty. Le role des interactions dans les choix fiscaux des agglomerations françaises. *Revue Française d'Economie*, 20(3), 2006.

[41] D. Quinn. The correlates of change in international financial regulation. *American Political Science Review*, 91:531–551, 1997.

[42] M. Redoano. Fiscal interactions among european countries. *Warwick Economic Research Papers*, 680, 2003.

[43] F. Revelli. Spatial patterns in local taxation: Tax mimicking or error mimicking? *Applied Economics*, 33:1101–1107, 2001.

[44] F. Revelli. Reaction or interaction? Spatial process identification in multi-tiered government structures. *Journal of Urban Economics*, 53:29–53, 2003.

[45] D. Rodrik. *Has Globalization Gone Too Far.* Institute for International Economics, 1997.

[46] J. Rork. Coveting thy neighbors' taxation. *National Tax Journal*, 56(4):775–787, 2003.

[47] F. Ruiz. Convergence de l'impôt sur les sociétés dans l'Union Européenne. *Economie et Prévision*, 173:79–96, 2006.

[48] F. Ruiz and M. Gérard. Summary, description, extensions of the capital income effective tax rate literature. In *International Taxation Handbook*, chapter 2, pages 11–42. Elsevier, 2007.

[49] J. Slemrod. Are corporate tax rates, or countries, converging? *Journal of Public Economics*, 88:1169–1186, 2004.

[50] A. Solé-Ollé. Electoral accountability and tax mimicking: The effects of electoral margins, coalition government, and ideology. *European Journal of Political Economy*, 19:685–713, 2003.

[51] P. Sorensen. Can capital income taxes survive? And should they? *Presented at Venice Summer Institute*, 2006.

[52] F. Stetzer. Specifying weights in spatial forecasting models: The results of some experiments. *Environment and planning A*, 14(5):571–584, 1982.

[53] D. Swank and S. Steinmo. The new political economy of taxation in advance capitalist democracies. *American Journal of Political Science*, 46 (3):671–692, 2002.

[54] J. Wilson. Theories of tax competition. *National Tax Journal*, 52:269–304, 1999.

[55] H. Winner. Hax tax competition emerged in OECD countries? Evidence from panel data. *International Tax and Public Finance*, 12 (5):667–687, 2005.

6 Appendix A. Estimation problems

Some main issues arise in the estimation of equation (1), notably the endogeneity of t_j's and possible spatial error dependence (see Anselin, 1988[3]).

The first issue, the endogeneity problem, especially results from the strategic spatial interaction among governments, which derives in the values of t being jointly determined. Writing (1) in matrix form

$$\tau = \beta W\tau + X\theta + \epsilon \tag{3}$$

where τ is an n by 1 vector of dependent variables, ϵ is an n by 1 vector of error terms, X is an n by K matrix of exogenous variables including the constant term, β and θ are as before and W is a n by n spatial weights matrix, typically standardized such that each row sums to one. The spatial weight matrix is necessary due to the lack of information to estimate a complete set of spatial interaction coefficients ($N(N-1)$) (where N here is the number of countries) and to circumvent the identification problem. By imposing a particular form for the spatial process, the model may be estimated and tested empirically.

Solving for τ, in the reduced form we obtain the following Nash equilibrium generated by interaction among governments

$$\tau = AX\theta + A\epsilon \quad \text{where} \quad A = (I - \beta W)^{-1} \tag{4}$$

Because of the random component of τ is equal to the inner product of A with the error vector ϵ, each tax depends on all ϵ's. The resulting correlation implies that the OLS estimator will be biased as well as inconsistent for the parameters of the model. To see this, observe that the OLS estimate of β in a pure first order spatial autoregressive model is $\widehat{\beta} = (t'_L t_L)^{-1} t'_L \tau$ (where $t_L = Wt$). If we substitute τ in the former expression we find that $\widehat{\beta} = \beta + (t'_L t_L)^{-1} t'_L \epsilon$

where the second term on the right-hand side does not have expectation zero, because τ and ϵ are not independent. Thus an OLS estimator of this model is biased. Moreover, if we divide the last part of the random term by N and take probability limits $p\lim N^{-1}(t_L'\epsilon) = p\lim N^{-1}\epsilon' W(I-\beta W)^{-1}\epsilon$ we find it will not equal zero with exception to the case when $\beta = 0$, implying that an OLS estimator is inconsistent.[10]

Two methods are usually used to deal with this problem. The first one is to estimate the reduced form equation (4) using maximum likelihood methods. The second way is an instrumental variable or two stage least squares approach. Anselin (1988) also proposes Bayesian techniques instrumented among others by LeSage (1997)[37].

The second issue, spatial error dependence (i.e. when the different jurisdictions are subject to correlated random shocks), produces that the standard assumption of a spherical error covariance matrix[11] fails to hold. Such spatial dependence can arise when the error term includes omitted variables, which are themselves spatially dependent. The most commonly used assumption is that the error vector satisfies the relationship:

$$\epsilon = \lambda W\epsilon + \phi \tag{5}$$

where λ is an unknown parameter, W is a weighting matrix (usually assumed to be the same as in 3) and ϕ is the i.i.d. error term with constant variance σ^2. Therefore, the error variance has the form $\sigma^2(I-\lambda W)^{-1}\left[(I-\lambda W)^{-1}\right]'$.[12]

The estimation in the presence of spatially dependent error terms requires a special approach given that inference based on the usual variance associated with

[10] The $p\lim N^{-1}\left(t_L' t_L\right)$ is a finite and nonsingular matrix with a proper structure to the spatial weight matrix and constraining $|\beta| < 1$.

[11] The sphericity assumption states that all variances are constant, i.e. the covariance matrix is a scalar multiple of the identity matrix ($\sigma^2 I$).

[12] Observe that the reduced form of (5) is $\epsilon = (I-\lambda W)^{-1}\phi$.

OLS estimates may be misleading. One approach is to use ML to estimate (3) considering (5) (this line was followed by Case et al.,1993[17]). Another remedy is to rely on IV estimation. Kelejian and Prucha (1998)[32] have demonstrated that even in the presence of spatial error dependence, IV method yields a consistent estimation of β, although it does not utilize information relating to the possible spatial correlation of the error term.[13] Finally, the third approach is to estimate the spatial lag model (3) by ML assuming error independence and using a hypothesis test to verify this absence (as in Brueckner and Saavedra, 2001).

7 Appendix B

7.1 Martinez-Mongay series

Martinez-Mongay calculated an effective capital income tax considering taxes on personal income from capital, taxes on corporate income and property taxes. The tax revenue from corporations is estimated taking the total direct taxes on income and wealth from AMECO (DTRV). Using the OECD Revenue Statistics databank, he calculates the proportion of "Corporate taxes on income, profits and capital gains" (1200) over the amount of direct taxation (i.e. "Taxes on income, profits and capital gains of individuals" (1100) + "Corporate taxes on income, profits and capital gains" (1200) + "Revenues from any kind of property taxes" (4000)). Therefore the corporate tax revenue (CORV) is equal to:

$$CORV = DTRV \times \frac{1200}{1100 + 1200 + 4000}$$

In the same way the property tax revenue (PWRV) is equal to:

[13] Kelejian and Prucha (1998) extend the spatial 2SLS model to include spatial error components.

$$PWRV = DTRV \times \frac{4000}{1100 + 1200 + 4000}$$

The tax revenue from taxes on personal income from capital is computing firstly estimating an effective tax rate on personal income (PITR), where as before the personal income tax revenue is:

$$PIRV = DTRV \times \frac{1100}{1100 + 1200 + 4000}$$

And the personal income tax base (PITB) is equal to:

$$\begin{aligned} PITB \quad = \quad & \underbrace{LETB - NWRV}_{\text{Household income from labour}} \quad + \\ & \underbrace{+NOS - \underbrace{(LETB - COEL)}_{\text{imputed wage of self-employed}} - CORV - PWRV}_{\text{household income from capital}} \end{aligned}$$

Where

$LETB$: Labor effective tax base (including self employment) = $\frac{\text{Total compensation of employees} \times \text{occupied population}}{\text{employees}}$

$NWLC$: Non-wage labor costs = $\frac{\text{Social security contributions}}{LETB}$

NOS: Net operating surplus of the economy

$COEL$: Total compensation of employees

Therefore

$$PITR = \frac{PIRV}{PITB}$$

And the capital effective tax rate (KETG) is:

$$KETG = \frac{CORV + PWRV + PITR \times \text{household income from capital}}{GOSA}$$

Where the tax base (GOSA) is the gross operating surplus adjusted for the imputed wage income of the self-employed

$$GOSA = GOS - (LETB - COEL)$$

7.2 BACH series

The BACH series were generated, following Nicodème, as the ratio of taxes paid on Gross Operating Profit,

$$\tau = \frac{T}{GOP}$$

using BACH database for the manufacturing enterprises.

7.3 Devereux, Griffith and Klemm series

Devereux, Griffith and Klemm calculate the EATR of the manufacturing sector as the difference between pre and post net present values of an investment in plant and machinery, scaled by the pre-tax total income stream, net of depreciation. This is analogous to other measures of average tax rates, in which observed tax payments are divided by a measure of pre-tax profit.

$$EATR = \frac{NPV^* - NPV}{\frac{p^*}{1+r}}$$

where the pre-tax NPV is

$$NPV^* = \frac{p^* - r}{1 + r}$$

p^* is a pre-tax rate of return to be fixed and r is the real interest rate.

The post-tax NPV is the difference between the present value of the income and the present value of the cost of the asset.

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

where δ is the economic rate of depreciation of the asset, τ is the corporate tax rate and A is the present value of allowances per unit of investment.

Devereux and Griffith show that the EATR can be rewritten as a weighted average of the EMTR and the statutory rate τ.

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

7.4 Corporate Tax Revenue / GDP series

The SGDP series were constructed as the ratio of "Corporate taxes on income, profits and capital gains" (1200), extracted from the "Revenue Statistics 1965-1999" cd-rom (OECD), on GDP

$$\tau = \frac{1200}{GDP}$$

8 Appendix C

Maximum likelihood

EATR	No spatial effects	W-1 eq w	W-2 inv min d	W-3 inv dist	W-4 inv gdp	W-5 inv gdp pe	W-6 cluster	W-7 sta tax
GEXP/GDP	-1,6678	-1,5454	-1,5596	-1,6656	-1,5038	-1,6313	-1,6931	-1,4776
	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Po65/Po	2,4292	2,2184	2,2968	2,4274	2,2376	2,4496	2,5813	2,5975
	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Size	0,7366	0,6742	0,7013	0,7326	0,6921	0,7234	0,6026	0,6077
	0,01	0,01	0,01	0,01	0,01	0,01	0,02	0,01
EU	-4,3954	-3,4103	-3,5973	-4,4356	-4,4375	-4,0885	-4,1777	-4,0213
	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
β (Wtax)		0,2567	0,2104	-0,0461	-0,1828	-0,2235	-0,1799	-0,4830
		0,00	0,00	0,72	0,04	0,01	0,00	0,00
Observations	260	260	260	260	260	260	260	260
R-squared	0,8665	0,8783	0,8750	0,8666	0,8697	0,8710	0,8730	0,8777
Log likelihood	-688,7300	-679,7853	-682,3386	-688,6905	-686,8353	-686,2395	-684,1794	-681,6790

St. Tax	No spatial effects	W-1 eq w	W-2 inv min d	W-3 inv dist	W-4 inv gdp	W-5 inv gdp pe	W-6 cluster	W-7 sta tax
GEXP/GDP	-1,7966	-1,7152	-1,7421	-1,7933	-1,6170	-1,7790	-1,8062	-1,6902
	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Po65/Po	5,2733	4,9458	5,0359	5,2738	5,0000	5,4064	5,2730	5,4140
	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Size	1,6507	1,5547	1,5796	1,6457	1,5812	1,6689	1,6200	1,5600
	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
EU	-5,9896	-4,8551	-5,1305	-6,0176	-5,7159	-5,8300	-6,0204	-5,8960
	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
β (Wtax)		0,2086	0,1765	-0,0371	-0,2609	-0,0935	-0,0240	-0,1560
		0,00	0,00	0,77	0,00	0,24	0,68	0,13
Observations	260	260	260	260	260	260	260	260
R-squared	0,8868	0,8940	0,8923	0,8869	0,8920	0,8875	0,8870	0,8881
Log likelihood	-745,7751	-739,1875	-740,8129	-745,7458	-741,9415	-745,4336	-745,6936	-744,8246

Figure 5: Maximum likelihood estimators.

Maximum likelihood

BACH	No spatial effects	W-1 eq w	W-2 inv min d	W-3 inv dist	W-4 inv gdp	W-5 inv gdp pe	W-6 cluster	W-7 sta tax
GEXP/GDP	-1,2462	-1,2967	-1,3028	-1,2639	-1,1675	-0,9893	-1,1797	-1,2229
	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Po65/Po	0,5307	0,4329	0,4391	0,3833	0,5496	0,2876	0,6267	0,0456
	0,30	0,34	0,33	0,37	0,22	0,49	0,16	0,92
Size	-0,2864	-0,2780	-0,2730	-0,2567	-0,2747	-0,2857	-0,1976	-0,3751
	0,39	0,34	0,34	0,35	0,34	0,28	0,49	0,18
EU	1,0266	1,1351	1,1495	1,1992	0,8941	1,4609	1,1372	0,9304
	0,32	0,21	0,20	0,16	0,32	0,08	0,20	0,28
β (Wtax)		-0,1210	-0,1310	-0,6987	-0,1751	-0,8013	-0,2150	-0,4400
		0,11	0,08	0,00	0,19	0,00	0,06	0,01
Observations	121	121	121	121	121	121	121	121
R-squared	0,8307	0,8355	0,8360	0,8514	0,8338	0,8616	0,8381	0,8465
Log likelihood	-248,0111	-246,8598	-246,8197	-244,1576	-247,3809	-241,8586	-246,3139	-244,3470

MM	No spatial effects	W-1 eq w	W-2 inv min d	W-3 inv dist	W-4 inv gdp	W-5 inv gdp pe	W-6 cluster	W-7 sta tax
GEXP/GDP	-0,1278	-0,1280	-0,1256	-0,1458	-0,0897	-0,1271	-0,1781	-0,1105
	0,24	0,21	0,21	0,13	0,37	0,20	0,07	0,26
Po65/Po	1,5526	1,5513	1,5706	1,6735	1,5448	1,4426	1,5116	1,6593
	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Size	0,2485	0,2479	0,2573	0,3364	0,2379	0,2175	0,2182	0,2169
	0,11	0,09	0,07	0,01	0,10	0,13	0,12	0,12
EU	3,0178	3,0105	3,0867	3,4418	2,9419	2,9867	2,8264	2,8268
	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
β (Wtax)		0,0037	-0,0328	-0,8382	0,1676	0,1515	-0,2550	-0,4250
		0,95	0,60	0,00	0,03	0,03	0,00	0,00
Observations	345	345	345	345	345	345	345	345
R-squared	0,8919	0,8919	0,8920	0,9029	0,8937	0,8941	0,8988	0,8987
Log likelihood	-743,7677	-743,7668	-743,6739	-737,4748	-742,0416	-741,2852	-736,2828	-736,4909

SGDP	No spatial effects	W-1 eq w	W-2 inv min d	W-3 inv dist	W-4 inv gdp	W-5 inv gdp pe	W-6 cluster	W-7 sta tax
GEXP/GDP	-0,1074	-0,1385	-0,1349	-0,1174	-0,1186	-0,1024	-0,1043	-0,1232
	0,07	0,01	0,01	0,02	0,02	0,06	0,05	0,01
Po65/Po	0,0318	0,0063	0,0202	0,0409	0,0375	0,0368	0,0407	-0,0597
	0,74	0,94	0,81	0,61	0,65	0,67	0,63	0,47
Size	0,0691	0,0671	0,0692	0,0750	0,0690	0,0713	0,0720	0,0621
	0,20	0,16	0,15	0,10	0,15	0,14	0,14	0,18
EU	0,7037	0,7541	0,7342	0,6754	0,6846	0,7058	0,7200	0,6349
	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
β (Wtax)		-0,2992	-0,2528	-0,9940	0,3296	-0,1395	-0,1520	-0,7370
		0,00	0,00	0,00	0,00	0,19	0,09	0,00
Observations	195	195	195	195	195	195	195	195
R-squared	0,8794	0,8866	0,8856	0,8961	0,8875	0,8806	0,8822	0,8954
Log likelihood	-144,1295	-140,7031	-140,8347	-137,5154	-140,2174	-143,5316	-142,6070	-136,2464

Figure 6: Maximum likelihood estimators.

2SLS

EATR								
	No spatial effects	**W-1 eq w**	**W-2 inv min d**	**W-3 inv dist**	**W-4 inv gdp**	**W-5 inv gdp pe**	**W-6 cluster**	**W-7 sta tax**
GEXP/GDP	-1,6678	-1,5073	-1,5430	-1,8013	-1,2354	-1,6275	-1,6744	-1,7324
	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Po65/Po	2,4292	2,1528	2,2764	2,5391	1,9241	2,4517	2,4691	2,3721
	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Size	0,7366	0,6548	0,6958	0,9781	0,6194	0,7220	0,7015	0,7804
	0,01	0,02	0,01	0,00	0,03	0,01	0,02	0,01
EU	-4,3954	-3,1037	-3,4745	-1,9801	-4,5065	-4,0560	-4,3383	-4,5224
	0,00	0,01	0,00	0,14	0,00	0,00	0,00	0,00
β (Wtax)		0,3366	0,2428	2,7731	-0,4821	-0,2472	-0,0472	0,1640
		0,01	0,06	0,00	0,01	0,21	0,70	0,61
Observations	260	260	260	260	260	260	260	260
R-squared	0,8666	0,8795	0,8756	0,8137	0,8694	0,8713	0,8688	0,8610
Log likelihood	-688,7319							

St. Tax								
	No spatial effects	**W-1 eq w**	**W-2 inv min d**	**W-3 inv dist**	**W-4 inv gdp**	**W-5 inv gdp pe**	**W-6 cluster**	**W-7 sta tax**
GEXP/GDP	-1,7966	-1,6649	-1,6893	-1,9469	-0,7377	-1,5749	-1,8826	-3,5087
	0,00	0,00	0,00	0,00	0,05	0,00	0,00	0,00
Po65/Po	5,2733	4,7431	4,8052	5,2524	3,6612	6,9576	5,2706	3,0096
	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01
Size	1,6507	1,4952	1,5104	1,8814	1,2411	1,8812	1,3774	3,1103
	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,00
EU	-5,9896	-4,1530	-4,2959	-4,6974	-4,3755	-3,9693	-6,2640	-7,4966
	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,00
β (Wtax)		0,3378	0,3479	1,7082	-1,5384	-1,1837	-0,2136	2,5105
		0,00	0,00	0,02	0,00	0,00	0,52	0,00
Observations	260	260	260	260	260	260	260	260
R-squared	0,8868	0,8946	0,8918	0,8654	0,8574	0,8764	0,8849	0,7338
Log likelihood	-745,7751							

Figure 7: IV estimators.