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2008

Online at <https://mpa.ub.uni-muenchen.de/21437/>
MPRA Paper No. 21437, posted 16 Mar 2010 15:22 UTC

Capital Tax Competition in the European Union: Theory and Evidence from Two Natural Experiments

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This version: October 17, 2008

Abstract

We investigate the effects of European integration on corporate tax competition. Both economic and monetary integration result in lower transaction costs in financial markets - by reducing capital controls, red tape and exchange rate uncertainty - and thereby in higher capital mobility. Nevertheless, monetary integration leads to a common pool problem vis-a-vis the shared revenues from issues of the common currency and to higher tax revenue needs due to lower inflation and the deficit constraints embedded in the stability pact. Economic integration may lead to access to better technologies, for the less developed members. It will also lead to more tax-responsive capital and higher user-cost of capital due to the abolition of tariffs. We show that monetary integration leads to lower taxes, while economic integration leads to higher taxes. Furthermore, we find robust evidence of a race-to-bottom effect. Throughout, we investigate the impact of EU enlargement.

Keywords: Tax Competition, Corporate Taxes, Neighboring Effects

JEL Classification Numbers: H0, H25, H77

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*We would like to thank seminar participants in University of Illinois at Urbana-Champaign and Keele University for helpful discussions and suggestions. The usual disclaimer applies.

1 Introduction

European Union (EU) is a major economic player in the world and a market that was based on what is known as the four basic freedoms, i.e. freedom of movement for goods (and hence no tariffs), services (and hence improvement in average quality of financial institutions and lower transaction costs), labor (leading to knowledge spillovers and improvements in average quality of technologies) and capital (leading to higher capital mobility). Moreover, the introduction, in most member countries, of the euro as a common currency creates a homogeneous monetary platform since it reduces exchange rate uncertainty, leading to a further decrease in transaction costs. It also leads to seignorage sharing.¹ It may also lead to lower inflation and public debt, if the move is associated with improvements in credibility of monetary-policy setting, and controls on national fiscal policies to reduce free-riding and pressures to the central monetary authorities to monetize national debts. All these can potentially have an impact on capital taxation in the Eurozone.

Aggregated at the EU level, total taxes collected represent today just fewer than 40% of GDP (compared to just fewer than 30% for the US and for Japan). The total tax burden has gradually increased between 1970 and the end of the last century. This increase is, in general, in conflict with the standard mechanism of tax competition, which has been the focus of an extensive literature. In fact, as the received literature has emphasized, the outcome of capital tax competition is indeed rather complex and depends on various characteristics.² Indeed, the outcome of non-cooperative capital-tax setting will depend, among others, on the (a)symmetry in the size and endowments of countries. The geographical location and the concentration of production, such as the existence of a core-periphery model, will also affect optimal levels of taxation across regions (Baldwin and Krugman, 2004; Devereux et. al., 2007a). In addition, trade between members of a union may lead to specialization and hence different equilibrium levels of taxation (Wilson, 1987). Echoing the theoretical literature, empirical studies also

¹The income of the European Central Bank is distributed between the national central banks, with the national banks being ultimately under the (financial) control of national governments. For the rules and provisions of the allocation of income between the national central banks see the .Protocol on the Statute of the European System of Central Banks and of the European Central Bank., especially Articles 28-33, (http://www.ecb.int/ecb/legal/pdf/en_statute_2.pdf).

²For some surveys of the capital tax competition literature, see Wilson (1999) and Brueckner (2003).

have shown that the availability of multiple tax instruments besides capital taxation (Rodrik, 1999 a,b), and the existence of international spillovers in public goods (Slemrod, 2004) and the degree of mobility of the factor(s) of production (Devereux and Griffith, 1998; Garretsen and Peeters, 2007) influence the effects of tax competition.

In this paper, we provide some theoretical results and investigate empirically the effects of economic and monetary integration on capital taxes. We take a general look at both the theoretical and empirical modelling of interactions in corporate tax setting, and ask some fundamental questions not yet addressed by the previous literature. On the theory level, we investigate the effects of tariffs, seignorage and technological changes on capital-tax setting. Special emphasis is placed on the dynamics of capital taxation in the presence of money, and possible links are drawn with the recent experience of European integration.³ Turning to our empirical investigation we, first, ask to what extent the joint estimation of both spatial and economic interactions affects the coefficients on the traditional regressor matrix in empirical corporate tax studies? Second, how robust are estimated spatial and economic relationships in tax patterns across alternative model specifications and different country groups? Given the existing literature, an obvious issue to examine in this regard is differences across samples of European Union (before and after the expansion of EU). Furthermore, because of the nature of spatial and economic effects, it is necessary to examine the simultaneous estimation of differences across geographic and economic sub-samples. Finally, we ask, to what extent can we measure the impact of the overall effects of economic and monetary integration on capital taxes?

The remainder of the paper proceeds as follows. In the next section we present and discuss our theoretical model. In Section 3 we discuss our empirical model. Section 4, presents the data, while Section 5 illustrates the definition of weights. Econometric issues are discussed in Section 6, and estimation results are presented in Section 7. Finally, Section 8 concludes.

³In Makris (2006) the focus is on capital tax externalities in a monetary union, in a static framework. Furthermore, in Makris (2008) the focus is on capital tax externalities in a model without money, in a two-period model. Here, however, the set-up is fully dynamic and both the cases of monetary autonomy and union are discussed and compared.

2 A Monetary Model of Capital Tax Competition

Here, we present a model with money and capital taxation under (imperfect) capital mobility. Its objective is to describe a particular mechanism of policy interdependencies between horizontally-related national governments. The precise nature of these interdependencies will be tested in Section 3-7.

2.1 The Economy

Our framework is the standard capital taxation model of Zodrow and Mieszkowski (1986) and Wilson (1986), appropriately modified to incorporate dynamics, money holdings, imperfect capital mobility and use of tariffs and public debt. There are $J > 1$ countries. Each country $j = 1, \dots, J$ is populated by N_j citizens indexed by $i = 1, \dots, N_j$. Time periods are indexed by $t = 1, 2, 3, \dots$

There is a single, composite and traded good. Assume for simplicity that there are no transportation costs. The single good of each period is produced in each and every country by means of combining capital and a fixed in supply factor of production, like land.⁴ Capital in period t is an intermediate good which is produced at the end of period $t - 1$ by means of using the composite good as an input. Assume without loss of generality that one unit of the composite good can be transformed into one unit of capital. The supply of capital in the first-period, $t = 1$, is pre-determined (by the associated use of the single good in the past).

Consider now the market for (financial) capital. It is assumed, for expositional simplicity, that only agents from these J countries can trade, possibly at some transaction costs, in this market.⁵ Perfect competition is the mode of trade in this market. Capital, K_{jt} , is ordered by

⁴The case of immobile between regions factors of production that are nevertheless non-fixed in supply would add additional complications without adding much in terms of insight. Arguably, in reality there are often production factors other than capital that are also mobile between regions. An example is labour. Nevertheless, it is also true that (financial) capital is in general more mobile than labour. For an important work along these lines see Kessler et. al. (2002). Note however that in that work the dynamics inherent in the accumulation of capital over time, the presence of money and the use of tariffs, which we emphasise, among others, here, are given short drift as there the model is static and with no money and tariffs. A very interesting line of future theoretical work would be to combine the set-ups of our paper and Kessler et. al. (2002).

⁵This assumption is without loss of generality qualitatively insofar we postulate that the J countries face a net supply of capital which is increasing with the world interest rate. In effect, allowing for capital trade between

the country- j firm at the end, and bought at prices, of period $t-1$. Also, to simplify exposition, let us assume that (financial) capital is supplied directly by households. Let ρ_t denote the *net* (or *after-tax*) real interest rate in this common market for capital.⁶

We assume that governments choose their policies to maximize welfare in their jurisdictions. We assume, for simplicity of exposition, that countries are small. In other words, the number of countries J is very large so that governments perceive the net real interest rates over time as being out of their control, despite the fact that eventually net real interest rates are endogenously determined by capital-market-clearing. The latter is discussed shortly.

2.1.1 The Governments

National governments produce local public goods by means of a technology that uses the private good as an input. Assume without loss of generality that the marginal product of the private good is equal to one. Expressed in real terms, denote with G_{jt} the level of public good. Fiscal revenue requirements are financed by means of a per-unit tax on real capital used domestically,⁷

the J countries and the rest of the world would only result in a less responsive interest rate to national fiscal policies. The assumption that the J countries do not trade in capital with the rest of the world could also be justified with reference to EMU and evidence that location decisions of US based multinationals have not been significantly affected by differences in effective tax rates across the Atlantic, while tax differences within Europe have had a significant effect (see Devereux and Griffith, 1998).

⁶The single market for capital is a short-cut representation of national financial capital markets that foreigners have access to, with no arbitrage opportunities. Let i_{jt} be the nominal interest rate in country j and period t . Let the before-tax price of the single good in country j in period t be P_{jt} . We then have that under that alternative representation, $\tilde{\rho}_{jt}$ is the real interest rate paid in period t by region- j firms to investors who have channeled their period- $t-1$ savings to country j . That is, $1 + \tilde{\rho}_{jt} \equiv (1 + i_{jt}) \frac{P_{jt-1}}{P_{jt}}$. Also, $\tilde{\tau}_{jt}$ is a tax paid by consumers on the nominal interest rate, and μ_{jt} is a per-unit transaction cost. So the income per-unit of investment in country j 's period- t capital is $1 + \tilde{\rho}_{jt} - \mu_{jt} - \tilde{\tau}_{jt} i_{jt} \frac{P_{jt-1}}{P_{jt}}$. No arbitrage implies that the net real interest rates $\tilde{\rho}_{jt} - \mu_{jt} - \tilde{\tau}_{jt} i_{jt} \frac{P_{jt-1}}{P_{jt}}$, for any j , are equalized across regions. Thus, investors are indifferent over the allocation of their savings to domestic or non-domestic capital. Also, K_{jt} equals the total real capital channelled to region j . Letting then ρ_t denote the common net-of-tax real interest rate across regions, and $\tau_{jt} \equiv \tilde{\tau}_{jt} i_{jt} \frac{P_{jt-1}}{P_{jt}}$ makes the two representations equivalent.

⁷To understand this let P_{jt} be the before-tax price of consumption. Let $\hat{\tau}_{jt}$ be a tax imposed on the domestic firm's period- $t-1$ spending on capital used for production in period t . Then, $\tau_{jt} \equiv \hat{\tau}_{jt} \frac{P_{jt-1}}{P_{jt}}$. One can also combine this with the environment of the previous footnote. In this case, firms pay $\hat{\tau}_{jt} \frac{P_{jt-1}}{P_{jt}}$ for each unit of capital, and we have $\tau_{jt} \equiv \hat{\tau}_{jt} \frac{P_{jt-1}}{P_{jt}} + \tilde{\tau}_{jt} i_{jt} \frac{P_{jt-1}}{P_{jt}}$.

τ_{jt} , a tax on expenditures on imports (a tariff), β_{jt} , and issues of new money and public debt.⁸

To discuss issuing of new money and public debt in more detail, let D_{jt} be the real level of country- j period- t *outstanding* public debt, in terms of period- $t-1$ consumption in country j . Assuming no arbitrage between private and public bonds, the country- j government's period- t total debt liabilities, in terms of period- t consumption in country j , are $(1 + \rho_t)D_{jt}$. On the other hand, the country- j government's period- t debt revenues, in terms of period- t consumption in country j , are D_{jt+1} .

Concerning money creation, we follow the accounting convention that national governments are responsible for *circulating* the currency *used* domestically regardless of the degree of monetary integration. Specifically, the circulated money will be the national currency when the country is not a member of a monetary union. It will, however, be replaced by the common currency following monetary integration. However, while in the former case the domestic governments are the ones who decide on the level of issued money, in the latter case, the currency is issued on behalf of the over-arching central bank. Let π_{jt} denote inflation in country j in period t . Under monetary independence inflation rates may differ across countries. Under monetary integration, however, countries face the same inflation rate.⁹ Let π_t denote the union-wide inflation rate in period t . In what follows, we will be using π_{jt} generically as the inflation rate of region j . It will be implied that, under a monetary union, $\pi_{jt} = \pi_t$ for any j . For expositional simplicity, we use, with some abuse of notation, the same letter for real money supply under both institutional cases. In more detail, let M_{jt} be the real value of the currency under circulation in period $t-1$ in country j , in terms of period- $t-1$ consumption in country j . Given this level of real money, the country- j government issues at the start of period t new money such that M_{jt+1} is the real value of the currency under circulation in period t in country j , in terms of period- t consumption in country j . Therefore, the real revenues generated by issues of new money in period t in country j , what we will refer to as *national seignorage*, are equal to $M_{jt+1} - (1 - \pi_{jt})M_{jt}$ in period t . Note, thus, that the period- t inflation rate is effectively a tax on period- $t-1$ real money stock.

Under monetary independence, governments enjoy exclusively their national seignorage.

⁸The model could easily be extended to the case of governments using also a tax on consumption expenditures and a tax on income from the fixed factor (i.e. a rents tax). We choose not to do so here for expositional simplicity.

⁹This follows directly from the absence, in equilibrium, of arbitrage with respect to union-currency issued and circulated in different regions.

Under monetary integration, however, regions share the union-wide seignorage created by the new issues of the common currency across countries. Let a_{jt} be the share of national seignorage retained by the national government. Assume also that each j -country's claims on the seignorage contributions of countries v and v' are the same for any v and v' . It follows that the seignorage the government in country j enjoys is equal to

$$a_{jt}(M_{jt+1} - (1 - \pi_{jt})M_{jt}) + \frac{1}{J-1} \sum_{\substack{v=1 \\ v \neq j}}^M (1 - a_{vt})(M_{vt+1} - (1 - \pi_{vt})M_{vt})$$

with,¹⁰ for any $j = 1, \dots, J$,

$$\begin{aligned} a_{jt} &= 1, \text{ under monetary autonomy, and} \\ a_{jt} &\in (0, 1), \text{ under monetary integration.} \end{aligned}$$

Let, in what follows,

$$\kappa_{jt} \equiv \frac{1}{J-1} \sum_{\substack{v=1 \\ v \neq j}}^M (1 - a_{vt})(M_{vt+1} - (1 - \pi_{vt})M_{vt}).$$

Denote by C_{jt} and Y_{jt} the country- j period- t real consumption and private good production, respectively. It follows that the period- t budget constraint of government in country j is

$$\begin{aligned} G_{jt} &= \tau_{jt}K_{jt} + a_{jt}(M_{jt+1} - (1 - \pi_{jt})M_{jt}) + D_{jt+1} - (1 + \rho_t)D_{jt} \\ &\quad + \beta_{jt}(C_{jt} - Y_{jt}) + \kappa_{jt}. \end{aligned}$$

2.1.2 The Firms

Let us turn to the description of the private sector. In each country j , a firm produces period- t output using technology $A_{jt}F_j[K_{jt}]$, with $F' > 0$, $F'' < 0$, where A_{jt} is a technology parameter.¹¹ Implicit in $F_j[\cdot]$ is the fixed factor, which is suppressed for expositional convenience.

¹⁰To understand the second part of the above formula, let first ϑ_j^v be the share of v -country's seignorage contribution appropriated by country j , with $\sum_{j \neq v} \vartheta_j^v = 1$ for any $v = 1, \dots, J$. So, the appropriated seignorage from abroad by country j is $\sum_v \vartheta_j^v (1 - a_{vt})(M_{vt+1} - (1 - \pi_{vt})M_{vt})$. After letting $\vartheta_j^v = \vartheta_j^{v'} \equiv \vartheta_j$ for any $j, v, v' = 1, \dots, J, v \neq j, v' \neq j$ and using $\sum_{j \neq v} \vartheta_j^v = 1$ for any $v = 1, \dots, J$ we have $(J-1) \sum_j \vartheta_j = J$. Thus, $(J-1)(1 + \vartheta_j) = J$ for any $j = 1, \dots, J$. Hence $\vartheta_j = \frac{1}{J-1}$ for any $j = 1, \dots, J$.

¹¹We will be using square brackets to denote functions, and brackets to denote collected terms in multiplications.

nience. Real profits are

$$\Pi_{jt} = (1 + \beta_{jt})(A_{jt}F_j[K_{jt}] + (1 - \delta_{jt})K_{jt}) - (1 + \rho_t + \mu_{jt} + \tau_{jt})K_{jt}.$$

In the above, μ_{jt} is a per-unit transaction cost on purchases of real capital. It captures, in a compact way, transaction costs in financing period- t real capital in country j . Also, δ_{jt} is the depreciation rate of real capital. Note that

$$Y_{jt} = A_{jt}F_j[K_{jt}] + (1 - \delta_{jt})K_{jt}.$$

Profit-maximisation for given prices and policies implies that

$$F'_j[K_{jt}] = r_{jt}, \tag{1}$$

where

$$r_{jt} \equiv \frac{\rho_t + \delta_{jt} + \mu_{jt} + \tau_{jt} - \beta_{jt}(1 - \delta_{jt})}{A_{jt}(1 + \beta_{jt})} \tag{2}$$

is the capital's user-cost. So, capital is a decreasing function of its user-cost r_{jt} : $K_{jt} = K_j[r_{jt}]$ with $K'_j = 1/F''_j < 0$. It follows directly from (2) that capital demand is decreasing with the net interest rate ρ_t , the depreciation rate δ_{jt} , the transaction costs μ_{jt} and the capital tax τ_{jt} , and is increasing with the tariff β_{jt} and technology A_{jt} . Also, we have

$$\Pi_{jt} = (1 + \beta_{jt})A_{jt}\Pi_j[r_{jt}],$$

where

$$\Pi_j[r_{jt}] \equiv F_j[K_j[r_{jt}]] - F'_j[K_j[r_{jt}]]K_{jt}[r_{jt}]$$

is the before-tax/subsidies return to the fixed factor as a proportion of the technological parameter A_{jt} .

2.1.3 The Consumers

For resident i in country j , preferences in period t are defined over consumption, C_{jt}^i , national public good, G_{jt} and real money balances held at the end of period t , M_{jt+1}^i . Real money balances here are defined as the units of the composite good that can be purchased in the period in question with the nominal money holdings acquired in that period. To understand the preferences over real money balances, note that here we focus on the role of money as a medium of exchange that reduces transaction costs associated with purchases of goods. That

is, individuals are viewed as benefiting from the *flow of services* yielded by money holdings. These services can be thought of as a description of the advantages of intermediate exchange. These advantages arise from the fact that converting illiquid assets to purchasing power and arranging barter transactions are costly, in terms of time and resources, activities. So, what matters, in terms of welfare, is the command of money holdings over goods or some measure of the transaction services that money holdings provide. In money-in-utility models, like the one here, the utility derived from the flow of services yielded by money holdings is related to the value, in terms of the composite good, of money holdings. In fact, models with money in utility can be viewed as shortcuts of models where money helps to reduce the time needed to purchase consumption goods.¹² In the context of our model, the presumption is that citizens gain utility from the real money balances they have at the end of a period, by economizing on the transaction costs that are involved in purchasing consumption goods at the end of that period.¹³ So, let temporal utility be

$$U_j^i[C_{jt}^i, M_{jt+1}^i]H_j^i[G_{jt}].$$

Assume that $U_{jC}^i > 0$, $U_{jCC}^i < 0$, $H_j^{i'} > 0$, $H_j^{i''} < 0$, and $U_{jM}^i > 0$. Preferences over public good are assumed to be separable for expositional simplicity.

Each citizen i in country j , decides in each period t upon her consumption, real money demand and purchases of real bonds (private and public) B_{jt+1}^i carried forward into the next period. In each period, her income consists of (a) her share of the net-of-tax/subsidies remuneration of the domestic fixed factor, (b) the returns from bonds brought forward from the previous period, and (c) the real money holdings brought forward from the previous period.

¹²Our results would be qualitatively similar if we have had, instead, a cash-in advance model. See Blanchard and Fischer (1989) Ch 4, Obstfeld and Rogoff (1996) Chs 8.1-8.3 and Walsh (2003) Chs 2 and 3 for some excellent discussions of the issues involved in modeling money in an analytically tractable way.

¹³An alternative environment would postulate that consumers gain utility from the real money balances they have at the start of a period, by economizing on the transaction costs that are involved in purchasing consumption goods at the end of that period. This assumption makes the timing of acquiring and using money more consistent with cash-in-advance models. See also Lucas (1982) and Carlstrom and Fuest (2001). Note that our results are qualitatively robust to allowing for this alternative timing.

The period- t budget constraint of consumer i in country j is given, in real terms, by:

$$B_{jt+1}^i + M_{jt+1}^i + (1 + \beta_{jt})C_{jt}^i = \\ (1 + \rho_t)B_{jt}^i + (1 - \pi_{jt})M_{jt}^i + \sigma_{jt}^i(1 + \beta_{jt})A_{jt}\Pi[r_{jt}],$$

where σ_{jt}^i is the consumer i 's share of the domestic fixed factor in period- t . Note here that the current user-cost of capital affects negatively the current net returns to the fixed factor and hence consumers' income. Also, the current net real interest rate affects positively the real returns to the past holdings of bonds. Moreover, current inflation affects negatively the real returns to past money holdings. Furthermore, the current tariff increases the after-tax price of consumption, while it increases the current net returns to the fixed factor and hence consumers' income.

After defining with θ_j^i the discount factor of consumer i in country j , utility maximisation for given prices and policies gives period- t demands for real money balances $M_{jt+1}^i[\rho_t, r_{jt}, x_{jt}, s_{jt}^i, A_{jt}]$ and bonds $B_{jt+1}^i[\rho_t, r_{jt}, x_{jt}, s_{jt}^i, A_{jt}]$, and a consumption function $C_{jt}^i[\rho_t, r_{jt}, x_{jt}, s_{jt}^i, A_{jt}]$, where $x_{jt} \equiv \{\beta_{jt}, \pi_{jt}\}$ and $s_{jt}^i \equiv \{B_{jt}^i, M_{jt}^i\}$. Note that, for expositional simplicity, we have suppressed here, and in what follows, the dependence of the various functions on δ_{jt} and σ_{jt}^i . Thus,¹⁴ equilibrium demands depend on (a) current prices, policies and technological parameters, $\rho_t, r_{jt}, x_{jt}, A_{jt}$, (b) past savings, with the latter being in the form of both bonds and money holdings, s_{jt}^i , and (c) anticipated future prices, policies and technological parameters. The latter is captured in a compact way by the time-dependence of the above demand functions. Note that the above optimal demands depend on r_{jt} and A_{jt} due to their impact on current income from the fixed factor. Denote the resulting temporal indirect utility by $V_{jt}^i[\rho_t, r_{jt}, x_{jt}, s_{jt}^i, A_{jt}]H_j^i[G_{jt}]$.

Let us assume normality of consumption. Also, as it seems to be a natural assumption given the postulated value of using money in our context, let us assume that $\frac{U_{jC}^i[C_{jt+v}^i, M_{jt+v+1}^i]}{U_{jM}^i[C_{jt+v}^i, M_{jt+v+1}^i]}$ is strictly decreasing with C_{jt+v}^i for any $v = 0, \dots, \infty$. That is, higher consumption raises the relative desirability of holding money. This, in turn, implies (see Appendix A), in conjunction with normality of consumption, that money is also a normal good. Thus, an increase in the user-cost of capital, which reduces capital and thereby income from the fixed factor, leads to a reduction, all other things equal, in consumption and money demand. Given that an increase

¹⁴The derivation of these functions is standard. We discuss it briefly in the Appendix A, for completeness.

in period- t inflation also reduces current income, we also have that consumption and money demand are strictly decreasing with current inflation.

2.1.4 Private Equilibrium

Equilibrium in the market for capital in period t is given by¹⁵

$$\sum_j K_j[r_{jt}] = \sum_j \left(\sum_i B_{jt}^i - D_{jt} \right) \equiv \bar{K}_t. \quad (3)$$

The left-hand side is the total demand for capital. The right-hand side is the total supply of capital. Notice that in period t , the supply of capital, \bar{K}_t , is pre-determined by the actions of consumers and governments in period $t - 1$. Recall the definition of capital's user-cost, (2). Thus, market-clearing implies an equilibrium net real interest rate $\rho_t = \rho[\vec{\tau}_t, \vec{\beta}_t, \vec{\mu}_t, \vec{A}_t, \bar{K}_t]$, where $\vec{\tau} \equiv \{\tau_1, \dots, \tau_J\}$, $\vec{\beta} \equiv \{\beta_1, \dots, \beta_J\}$, $\vec{\mu} \equiv \{\mu_1, \dots, \mu_J\}$, and $\vec{A} \equiv \{A_1, \dots, A_J\}$. Clearly, higher supply of capital, higher transaction costs and capital taxes, and lower technology and tariffs lead to a lower net real interest rate.

Equilibrium in the region- j market for money in period t , under both national and common currencies, is given by

$$\sum_i M_{jt+1}^i[\rho_t, r_{jt}, x_{jt}, s_{jt}^i, A_{jt}] = M_{jt+1}.$$

The left-hand side is the total demand for, and the right-hand side is the supply of, real money.

2.1.5 Policy-Setting

At this stage we can discuss what constitutes monetary policy in our set-up. Given the equilibrium net real interest rate, and the regional user-costs of capital and import taxes, the above equilibrium condition determines implicitly a relationship between inflation π_{jt} and real money supply M_{jt+1} . Given that demand for real money in period t is strictly decreasing with current inflation π_{jt} , we have that this relationship is strictly negative. Hence, one can think of national governments setting (independently or on behalf of the union central bank) domestic inflation and adjusting their money supplies accordingly, so that money-market equilibrium is satisfied given private decisions. This will be the convention we will follow hereafter.

¹⁵Given equilibrium in the market for money, and that capital is an intermediate good supplied by consumers, capital-market-clearing is equivalent to equilibrium in the market for the composite traded good.

We focus on credible policy-setting by national governments. In more detail, governments choose their policies, in each period, after savings (i.e. money and asset holdings) are determined but before firms decide on their capital demands. Note that in such an environment the supply of capital in each period is pre-determined. Nevertheless, capital taxes do affect the allocation of capital between regions. Therefore, capital tax competition is still possible. So, we investigate an environment where governments compete for a given stock of capital on a period-per-period basis. We also assume, as it is standard in analysis of credible tax-setting, that $\sum_j N_j$ is very large so that consumers perceive themselves very small to affect current and, crucially, future policies.

It is well known that in dynamic non-cooperative games multiplicity of equilibria may arise. We focus on sub-game perfect equilibria in differentiable (pure) Markov tax-strategies. For a discussion of the advantages of Markov strategies in dynamic games see Fudenberg and Tirole (1992) Ch. 13. Differentiability is required for analytical simplicity.

Markov strategies imply that actions in a given period depend on past history only through the ‘state’. The ‘state’ is a (possibly multi-dimensional) variable which summarizes the influence of past interactions on the current strategic environment. In other words, the state is the *minimal* information in the history of a game which is relevant for the strategic interaction between players. In our context, the state in any period t , Q_t , is the money and bond holdings, and the public debt issued, in the previous period in each region, i.e. $Q_t \equiv \{Q_{jt}\}_{j=1}^J \equiv \{M_{jt}^1, \dots, M_{jt}^{N_j}, B_{jt}^1, \dots, B_{jt}^{N_j}, D_{jt}\}_{j=1}^J$.

In a Markov Perfect Equilibrium (MPE), national policies, τ_{jt} , D_{jt+1} and x_{jt} , $j = 1, \dots, J$, in each period t are a Nash equilibrium given the state Q_t and the rationally anticipated response of all regional governments with respect to their future policies to period- t -policy-induced changes in future states (inflation is taken as given under monetary integration). Governments take also into account the effects of their policies on the optimal behaviour of firms and consumers.

2.1.6 Non-Cooperative Capital Taxes

For our purposes it is sufficient to focus on the setting of the current capital taxes τ_{jt} , in some region j , for given period- t (MPE) inflation rate, π_{jt} , public debt policy, $d_{jt} \equiv D_{jt+1}$, and taxes on imports, β_{jt} , and foreign transfers, κ_{jt} . So, let $T_{jt}[Q_{jt}]$ be the corresponding Markov tax-strategy of j -government, with $T_{jt}[\cdot]$ being differentiable. Note that we have

suppressed the dependence of $T_{jt}[\cdot]$ on κ_{jt} , x_{jt} , d_{jt} , A_{jt} , μ_{jt} , a_{jt} and $\{\rho_t, \rho_{t+1}, \dots\}$ for expositional simplicity. Let also $W_{jt}[Q_t, \rho_t]$ denote the period- t value function of the j -government for given net real interest rate and state, after having suppressed its dependence on a_{jt} , A_{jt} , μ_{jt} and $\{\rho_{t+1}, \rho_{t+2}, \dots\}$ for expositional simplicity. Furthermore, let $Q_{jt+1}[Q_{jt}, r_{jt}, x_{jt}, d_{jt}, \rho_t]$ represent in a compact way the state-evolution in a MPE, after suppressing for expositional simplicity its dependence on A_{jt} . That is, we have that in a MPE $Q_{jt+1} = Q_{jt+1}[Q_{jt}, r_{jt}, x_{jt}, d_{jt}, \rho_t]$ describes in a compact way the following:

$$\begin{aligned} D_{jt+1} &= d_{jt}, \\ M_{jt+1}^i &= M_{jt+1}^i[\rho_t, r_{jt}, x_{jt}, s_{jt}^i, A_{jt}], \\ B_{jt+1}^i &= B_{jt+1}^i[\rho_t, r_{jt}, x_{jt}, s_{jt}^i, A_{jt}]. \end{aligned}$$

We then have that Markov tax-strategies, for any given x_{jt} , d_{jt} , A_{jt} , μ_{jt} , κ_{jt} , a_{jt} and $\{\rho_t, \rho_{t+1}, \dots\}$, are given by:¹⁶

$$\begin{aligned} \max_{\tau} \{ & \sum_i V_{jt}^i[\rho_t, r_{jt}, x_{jt}, s_{jt}^i, A_{jt}] H_j^i[G_{jt}] + \theta_j^i W_{jt+1}[Q_{t+1}, \rho_{t+1}] \} \\ \text{subject to } & Q_{jt+1} = Q_{jt+1}[Q_{jt}, r_{jt}, x_{jt}, d_{jt}, \rho_t], \\ & G_{jt} = \tau K_j[r_{jt}] + d_{jt} - (1 + \rho_t) D_{jt} \\ & + a_{jt} \left(\sum_i M_{jt+1}^i[\rho_t, r_{jt}, x_{jt}, s_{jt}^i, A_{jt}] - (1 - \pi_{jt}) M_{jt} \right) + \kappa_{jt} \\ & + \beta_{jt} \sum_i C_{jt}^i[\rho_t, r_{jt}, x_{jt}, s_{jt}^i, A_{jt}] \\ & - \beta_{jt} (A_{jt} F_j[K_j[r_{jt}]] + (1 - \delta_{jt}) K_j[r_{jt}]), \text{ and} \\ & r_{jt} \equiv \frac{\rho_t + \delta_{jt} + \mu_{jt} + \tau - \beta_{jt}(1 - \delta_{jt})}{A_{jt}(1 + \beta_{jt})}. \end{aligned}$$

Note that, for any given net real interest rate, foreign policies have no direct impact on domestic decisions insofar foreign transfers remain unaffected.

After using the envelope theorem, the first order condition (f.o.c.) is:

$$E_{jt} = 0,$$

¹⁶For more details see Appendix B.

where

$$E_{jt} \equiv (1 - \eta_{jt}[r_{jt}, \tau_{jt}, A_{jt}, \beta_{jt}] + R_{jt})\lambda_{jt} - \frac{1}{1 + \beta_{jt}} + \Phi_{jt}. \quad (4)$$

In the above condition,

$$\eta_{jt}[r_{jt}, \tau_{jt}, A_{jt}, \beta_{jt}] \equiv -\frac{\tau_{jt}}{A_{jt}(1 + \beta_{jt})} \frac{K'_j[r_{jt}]}{K_j[r_{jt}]} \quad (5)$$

is the tax-elasticity of capital. Furthermore, Φ_{jt} is a measure of the marginal effect of the capital tax, through the capital's user-cost, on future welfare, relative to current national capital. In general, the sign of this is ambiguous; it depends, among others, on the income elasticity of savings.¹⁷ In addition, R_{jt} is the marginal effect of the capital tax, through the capital's user-cost, on seignorage and the government revenues from tariff, relative to current national capital. Note that the sign of it is ambiguous. On the one hand, a capital-tax-induced increase in the capital's user-cost reduces, by normality, money demand and consumption, and hence revenues from seignorage and taxes on imports. On the other hand, a capital-tax-induced increase in the capital's user-cost reduces demand for capital and hence output, which, in turn, implies an increase in revenues from tariffs. Moreover, $\lambda_{jt} > 0$ is the total marginal utility of the public good relative to the total marginal utility of private consumption weighted by the share of the fixed factor. Φ_{jt} , R_{jt} and λ_{jt} are stated formally in Appendix C.

The f.o.c. above represents, as a proportion of current capital and the total weighted marginal utility from consumption, the balance in equilibrium between the marginal cost, $\frac{1}{1 + \beta_{jt}}$, and the marginal benefit, $(1 - \eta_{jt}[r_{jt}, \tau_{jt}, A_{jt}, \beta_{jt}] + R_{jt})\lambda_{jt} + \Phi_{jt}$, of a higher capital tax. The former arises from the decrease in the current income from the fixed factor, and hence in current consumption, due to higher capital-user-cost. The latter consists of a number of effects. In more detail, $(1 - \eta_{jt}[r_{jt}, \tau_{jt}, A_{jt}, \beta_{jt}])\lambda_{jt}$ represents the marginal welfare benefit from the net increase in current government revenues, and hence public good provision, from capital taxation. Furthermore, $R_{jt}\lambda_{jt}$ represents the marginal welfare effect from the net change in current government revenues from issuing money and taxing imports. Finally, Φ_{jt} represents

¹⁷For a theoretical investigation of Φ_{jt} in a related model see Makris (2008). There the emphasis is on the intertemporal externalities that emerge when capital is taxed in a two-period environment.

the marginal welfare effect from the net change in future consumption, private and public, due to tax-induced changes in the future state and thereby in future policies.

2.1.7 The Capital Tax Reaction Function

With a view to our forthcoming empirical investigation let us discuss here the dependence of MPE capital taxes on various policies and the output-augmenting technologies. We have that (4) determines implicitly the equilibrium tax in period t and region j as a function of the national capital user-cost, r_{jt} , *public-good valuation*, λ_{jt} , tariffs, β_{jt} , output-augmenting technology, A_{jt} , and the marginal effects R_{jt} and Φ_{jt} : $\tau_{jt} = \tilde{\tau}_{jt}[r_{jt}, \lambda_{jt}, \beta_{jt}, A_{jt}, \Phi_{jt}, R_{jt}]$.

Note from (4) and (5) that E_{jt} is strictly decreasing with the capital tax for any given $r_{jt}, \beta_{jt}, \lambda_{jt}, \Phi_{jt}, R_{jt}$ and A_{jt} . We, therefore, have that the sign of the partial derivative of E_{jt} with respect to any of these determinants of the capital tax gives us also the direction of the this determinant's effect on the capital tax. Note then, by totally differentiating E_{jt} for *given* capital tax, and using (4) once again, that

$$\begin{aligned}
d\tau_{jt} \propto & \lambda_{jt}dR_{jt} + d\Phi_{jt} \\
& + \left\{ \frac{1}{(1 + \beta_{jt})^2} + \lambda_{jt} \frac{\eta_{jt}}{(1 + \beta_{jt})} \right\} d\beta_{jt} \\
& + \lambda_{jt} \frac{\eta_{jt}}{A_{jt}} dA_{jt} \\
& + \lambda_{jt} \frac{\tau_{jt}}{A_{jt}(1 + B_{jt})} \frac{\partial(K'_j[r_{jt}]/K'_j[r_{jt}])}{\partial r_{jt}} dr_{jt} \\
& + \left\{ \frac{1}{1 + \beta_{jt}} - \frac{\Phi_{jt}}{\lambda_{jt}} \right\} d\lambda_{jt}.
\end{aligned} \tag{6}$$

The fifth term above represents the standard *user-cost effect*. This effect arises as a higher user-cost, all other things equal, leads to a change in the tax-elasticity of capital that has the opposite sign of $\frac{\partial(K'_j[r_{jt}]/K'_j[r_{jt}])}{\partial r_{jt}}$. So, if the latter is positive - as it is often assumed in the standard capital tax competition literature (and is the case with a Cobb-Douglas production function $F[k] = k^\alpha$) - we have that, when capital taxes are positive, a higher user-cost leads to higher capital taxes. Assume hereafter to fix ideas that, indeed, $\frac{\partial(K'_j[r_{jt}]/K'_j[r_{jt}])}{\partial r_{jt}} > 0$. Thus the user-cost effect is *positive*. A straightforward implication, given that the capital user-cost and transaction costs are positively related from (2), is the typical prediction that lower transaction costs lead, all other things equal, to lower capital taxes.

The third term above represents the *tariff effect*, and is *positive*. That is, a higher tariff will lead to a higher capital tax, all other things equal. The reason is that higher tariffs lead

to (a) higher consumer prices and thereby a lower capital-tax-induced decrease in income from the fixed factor and hence in consumption, (b) lower capital-tax-induced decrease in domestic capital-tax base.

The fourth term above represents the *technology effect*, and is also *positive*. That is, a higher output-augmenting technology will lead to a higher capital tax, all other things equal. The reason is that better production technology leads to a lower capital-tax-induced decrease in domestic capital-tax base.

The sixth term above represents the *public-good-valuation effect*. If public good provision is increasing with the capital tax in equilibrium, i.e. $\frac{1}{1+\beta_{jt}} > \Phi_{jt}$, then this effect is *positive*. That is, a higher total marginal utility of the public good relative to the total weighted marginal utility of private consumption will lead to a higher capital tax, all other things equal. The reason is straightforward: if the capital tax “is to the left of the Laffer curve”, then higher relative value for public good will lead to a higher capital tax. Assume hereafter, to fix ideas, that, indeed, in equilibrium, a higher capital tax will lead to more public good, and hence that the effect in question is *positive*.

Finally, we have the first and second terms that represent the *revenue* and *dynamic effects*, respectively, and both are of *positive* sign. Starting from the revenue effect, we thus have that if the net capital-tax-induced gain in current revenues from seignorage and import taxes, R_{jt} , increases, then, as intuition would suggest, the capital tax increases as well. Turning to the dynamic effect, if the net capital-tax-induced future welfare gain from affecting future economic actions, Φ_{jt} , increases, then the current capital tax will be higher, *ceteris paribus*.

Notice that λ_{jt} , R_{jt} and Φ_{jt} depend also, among other important determinants, on import taxation, output-augmenting technology, the user-cost of capital, the net real interest rate, inflation and past private savings. After some tedious calculations, one can see that the effects of these determinants on λ_{jt} , R_{jt} and Φ_{jt} cannot be signed unambiguously unless further restrictions are imposed on the fundamentals of the model. Given the empirical investigation in the second part of the paper, we therefore abstain from discussing these effects here. For completeness, however, we do so in Appendix D.

Importantly, for the purposes of our study, λ_{jt} depends also on the net increase in public debt and money supply, on interest payments on past public debt and on seignorage sharing under monetary integration - through their effect on the level of public consumption. Specifically, if a change in these determinants results in higher public consumption, then the relative

valuation of public good decreases. As we have seen above, this will lead to higher capital taxes.

Recall from (2) that the user-cost of capital depends positively on the net real interest rate. The latter, however, is determined endogenously from the capital-market-clearing (recall (3)). It follows then directly that the domestic user-cost of capital depends also on foreign capital taxes, tariffs, technologies and transaction costs. In fact, any change in these variables that increases foreign user-costs of capital, will lead to lower demand for capital and hence a lower net real interest rate. This, in turn, will imply a lower domestic user-cost of capital. One can also easily see that the net effects of domestic tariffs, technology and transaction cost on the domestic user-cost of capital have the signs of the corresponding direct effects discussed earlier (recall (2)).¹⁸

The above discussion indicates that domestic policies, and hence, capital tax depend on foreign capital taxes,¹⁹ foreign and domestic transaction costs and output-augmenting technologies, the extend of seignorage sharing under monetary integration, exogenous restrictions on tariffs, issues of new public debt and money, and inflation. In fact,²⁰ with the empirical investigation in mind, one can think of the following capital tax reaction function for country j in period t :

$$\tau_{jt} = \tau_j[t, \pi_{jt}, d_{jt}, y_{jt}^*, \iota_E, \iota_M], \quad (7)$$

where, recall, d_{jt} denotes issues of new public debt in period t in country j , and π_{jt} denotes the inflation rate.

The dependence of the above tax-function on time index t captures the dependence of the tax on the state of the economy (that summarizes the influence of past decisions on current strategic environment) and on expectations about future economic conditions. This will be captured by time effects, the effect of lagged values of the domestic capital tax and by

¹⁸These are formally discussed in Appendix D.

¹⁹Foreign tariffs and, under monetary autonomy, foreign inflation rates are endogenously determined alongside capital taxes across countries. One can then eliminate foreign tariffs and inflation rates from the conditions that give capital taxes across countries, by using the equilibrium conditions for the determination of foreign tariffs and inflation rates.

²⁰Domestic tariffs are also endogenously determined alongside capital taxes. One can then eliminate domestic tariffs from the condition that gives domestic capital taxes, by using the equilibrium condition for the determination of domestic tariffs.

incorporating various control variables like population and unemployment.

Furthermore, y_{jt}^* is a vector-variable that captures the influence of foreign capital taxes, and foreign variables like transaction costs and technology, on domestic tax-setting. Foreign capital taxes will be one of the explanatory variables. The effects of the foreign economic conditions will be captured by the explicit consideration of economic neighboring effects in our econometric investigation.

Finally, ι_E and ι_M are indicator functions that capture the dependence of capital-tax setting on the presence of economic integration - a la EU - and monetary integration - a la EMU, respectively. Notice here that the monetary integration indicator function, ι_M , captures the impact of monetary integration on capital taxes over and above the impact that may result from the possible effects of monetary integration on inflation and public debt.

The overall effects of economic and monetary integration on capital taxes is the main focus of our paper. Therefore, it is worth emphasising the anticipated implications for capital taxes of European integration, given the predictions of our theoretical model above.

2.1.8 Some implications of Economic Integration

Economic Integration of the type that took place in Europe may have the following effects. First, it will improve capital mobility, represented here by a decrease in μ_{jt} . The direct effect is to reduce the capital's user-cost and hence, by the user-cost effect, to push towards lower taxes. This effect of higher capital mobility is the main ingredient of any existing model of capital tax competition.²¹

Second, it will enforce zero tariffs. The direct effect of this is (recall the tariff effect) a decrease in capital taxes. An indirect effect of a decrease in tariffs, however, is an increase in the user-cost. This, in turn implies, by the user-cost effect, that capital taxes will increase, all other things equal.

Third, through the mobility of knowledge and the improvements in the institutional and legislative framework, it might lead to improvements in technology, represented here by an increase in A_{jt} . This will have two main effects for countries that were less developed prior

²¹An increase in capital mobility has also indirect effects through the relative marginal valuation of public good, the capital-tax-induced change in tariff revenues and seignorage, and the capital-tax-induced change in future welfare. However, the corresponding net effects cannot be signed unless further restrictions are imposed on the fundamentals of the model.

to integration. The direct effect is (recall the technology effect) an increase in capital taxes. Improvements in technology, however, will also lead to a reduction in the user-cost of capital. Thus, by the user-cost effect, capital taxes will decrease, all other things equal.²²

Therefore, economic integration will have an ambiguous effect on capital taxes.

2.1.9 Some implications of Monetary Integration

Monetary Integration of the type that took place in Europe may have the following effects. First, it will (further) improve capital mobility. Hence, after recalling the corresponding discussion under economic integration, it may push towards (even) lower taxes.

Second, recall that entering a monetary union implies seignorage sharing. This is represented here by a decrease in the seignorage share a_{jt} and a reduction in the foreign seignorage shares (and hence an increase in the transfer κ_{jt} , for any given levels of seignorage across countries). By their impact on domestic public revenues, and thereby by the public-good-valuation effect, this will have two opposite effects. In more detail, the first is pushing for a higher, while the latter for a lower capital tax. Moreover, a lower domestic seignorage share increases R_{jt} . Therefore, by the revenue effect it leads, all other things equal, to a higher capital tax. So, seignorage sharing will have an ambiguous effect on the capital tax. The exact effect will depend, among others, on the extent at which a country is a net contributor of seignorage. That is, if entering a monetary union implies a net decrease in appropriated revenues from issues of new money, then the capital tax will tend to increase.²³

Therefore, monetary integration per se will also have an ambiguous effect on capital taxes. This effect may also be asymmetric due to the possibly different reliance of countries on seignorage prior to entering a monetary union.

We leave this section by noting that, through a possible reduction on average inflation and debt-financing, monetary integration may also reduce public good provision, all other things equal. In this case, the relative marginal valuation of the public good will increase and, by the

²²Improvements in technology and a reduction in tariffs have also indirect effects, through their impact on the relative marginal valuation of public good, on the capital-tax-induced change in tariff revenues and seignorage, and on the capital-tax-induced change in future welfare. However, the corresponding net effects cannot be signed unless further restrictions are imposed on the fundamentals of the model.

²³The discussion here draws on unpublished work, within a very stylized two-period model, that had been circulated by the second author in the past.

public-good-valuation effect, taxes will tend to increase. Lower inflation will also, by normality, increase consumption and money demand, and thereby revenues from tariffs and issues of new money. This, in turn, will lead, by the public-good-valuation effect, to lower taxes. Lower levels of public debt will also lead to higher supply of capital and hence a lower net real interest rate and lower national user-costs of capital. This will tend to push to lower capital taxes, due to the user-cost effect. Thus, the net effect of lower levels of public debt and inflation will also be ambiguous.²⁴

We turn to the empirical investigation of capital taxes.

3 Empirical Specification

Our theoretical framework suggests that we want to estimate the reaction functions as characterized above. Specifically, in our set-up, t_{iq} (the marginal tax rate) is the dependent variable. Turning to the explanatory variables of the model, Devereux et. al. (2007) examine whether discretionary government grants influence where domestic and multinational firms locate new plants, and how the presence of agglomeration externalities interact with these policy instruments. Following their model we try to estimate the presence of neighboring effects (clusters) in marginal corporate taxes and we find that both EU entrance and adoption of Euro have an impact on the creation of agglomeration spillovers. Moreover, we include at the model a country fixed effect ζ_i , a vector of country specific controls X_{iq} and a vector of dummy variables D_{iq} ; related to the participation at the European Union (EU) and the adoption of Euro. The general form of the discussed specification is

$$\tau_{it} = \zeta_i + a_{it} \sum_{\substack{j=1 \\ j \neq i}}^J w_{ij} \tau_{jt} + \gamma_{it} \sum_{\substack{j=1 \\ j \neq i}}^J s_{ij} \tau_{jt} + z_{it-1} \tau_{it-1} + \xi'_{it} X_{it} + \eta'_{it} D_{it} + \varepsilon_{it} \quad (8)$$

where $i = 1 \dots J$ denotes a country, and $t = 1 \dots k$ a time-period. Spatial weights are denoted by w and economic weights by s . A detailed discussion about those weights follows at a subsequent section. The expanded autoregressive model (8) is estimated as the standard spatial

²⁴Reduction in inflation and public debt levels have also indirect effects, through the relative marginal valuation for public good, the capital-tax-induced change in tariff revenues and seignorage, and the capital-tax-induced change in future welfare. However, all corresponding net effects cannot be signed unless further restrictions are imposed on the fundamentals of the model.

autoregressive model,²⁵ provided that the above formulations of weights are sufficiently different and do not contain entirely overlapping information. Moreover, we account for temporal effects (z) by including the lagged value of marginal tax rates. These temporal effects stem, as theory suggests, from the impact on consumers' behavior and fiscal revenue requirements of domestic and foreign past bonds, debt and money.

The specification of equation (8) raises a number of issues for the empirical estimation. Those issues are explicitly discussed at a following subsection.

4 Data

We present results using as a dependent variable corporate tax rates, and specifically the top national corporate tax rates. The sources of data are the World Development Indicators (2006), European Commission (2006) and KPMG's Corporate Tax Rate Survey (2006). Those sources provide information for a broad sample of countries, for the period 1975-2005. Figure 1 provides an insight about GDP-weighted average taxes for the above period.

Add here Figure 1: Taxes as a % of GDP in EU

For several years (1970 – 1986), we observe an increase of the total tax burden, and a small decline in the last three years. This hides of course a large diversity in levels and trends across European Countries as well as the influence of the economic cycle.

International comparability of the data is made possible through use of various controls for differences in coverage and definitions. We check for the robustness of empirical results for capital tax rates when controls for differences in coverage are included.

Explanatory variables²⁶ also include the added value of Agricultural sector (Baunsgaard and Keen, 2005) and trade as a fraction of GDP to measure openness. To control for the effect of prices, we include inflation. This variable captures cost-of-living differences not captured by exchange rate conversions. As suggested by Devereux et al., (2007a) and Rodrik (1999a), we also include the level of GDP to account for economic variation. We also augment our model

²⁵The choice of the lag formulation is based on spatial diagnostic tests (LM-Error and LM-Lag).

²⁶See Table A1 for summary statistics and information.

specification with additional variables such as debt-to-GDP ratio, the level of market capitalization (in particular, market capitalization of listed companies (% of GDP)), unemployment as a percentage of total labor force), wages (measured by workers’ remittances and compensation of employees) and population. All these variables are highlighted in the literature²⁷ as a means of controlling for country and economic characteristics. Furthermore, to allow for the effect of European integration, we decompose it into two variables. One of these represents the entrance of the country in the European Union and the second denotes the key year of adoption of the common currency.

5 Weight Specification

An important decision in model estimation is the choice of the connectivity weights. Explanatory data analysis typically provides a possible way of getting information about the structure of the data. However, a method that is often used in practice and suggested by the existed literature is to apply some weight matrices in regression analysis and test for the presence (if any) of dependence with each of the matrices.²⁸ We employ in the regression analysis weighted averages of tax rates in competing countries, following the standard spatial regression literature as summarized by Anselin (1988). The spatial weight matrix for country i takes the form, W_i . Its elements w_{ij} specify a “neighborhood set” for each observation i . In more detail, w_{ij} is positive if j is a “neighbor” of i , and zero otherwise. Indeed, this structure is given by what is known as the “connectivity matrix”, which specifies the degree of connectivity (weights) between any two observations.²⁹ Essentially, we use the inverse distance-based matrix, where weights³⁰ are specified as a decaying function in space – that is, as $w_{ij} = (d_{ij})^{-2}$, with d_{ij} denoting distance between countries i and j .

In our model, we consider many forms of the weighting matrix, based on economic criteria; provided that the matrices are sufficiently different and that do not contain entirely overlapping

²⁷See Devereux et al (2007a) and Rizzo (2007).

²⁸For alternative specifications of weight matrices see Anselin (1988).

²⁹The assumption that these weights are known a priori is strong, although it is crucial for the method to work. Of course, it is no stronger than the typical implicit assumption that all weights are zero, that is, all observations are spatially independent.

³⁰As a robustness exercise, we tested alternative spatial criteria and results do not present significant variations.

information³¹. First, countries are assigned to be “neighbors” if they have a similar level of GDP. Actually, we discriminate among high and low GDP type countries by dividing the sample into two groups. In a non-geographic context, the notion of “distance” is determined by the relative magnitude of GDP and a country is connected to all other countries of the same GDP-type (high-low). The GDP connectivity matrix differs from any distance matrix in two notable ways. First, the GDP matrix consists of weights where the importance of another state j to state i is given by the relative magnitude of the GDP. Second, the GDP connectivity matrix weights high type partners much more heavily than low type partners, whereas in the distance matrix, any neighbor of i must always have j as a non-trivial neighbor. Therefore, the elements of GDP connectivity matrix are defined as:

$$s_{ij} = 1 - \left| \frac{GDP_j - GDP_i}{GDP_j + GDP_i} \right| \quad (9)$$

and by construction, this index ranges from 0 to 1. In particular, if the proportion of GDP is the same between the two countries, then $s_{ij} = 1$. The elements of GDP connectivity matrix take the value of 0 if the the difference in GDP values is really significant. Notice that this definition of similarity is symmetric in that $s_{ji} = s_{ij}$. Finally, it is created using the temporal average values of each country.

A second form of the weighting matrix is based on market capitalization weights i.e. countries with similar market capitalization (% of GDP). Thirdly, we define weighted schemes based on the wages and, finally, according to the aggregate export activities. The algebraic definitions of those weights are similar to the one with the GDP specification. These weighting matrices were used to create weighted averages of corporate tax rates in “neighbor” countries.

One interesting feature of the export matrix is that more-open countries have the bulk of their export activities with large, wealthy, countries, which more often depict a higher demand for capital. As a result, these countries will tend to have a higher “connectivity lag” (neighbors with many over countries) than the distance based connectivity lag. In other words, the magnitude of the discussed weight is greater than the corresponding distance based weight.

³¹For further details see Brueckner, 2003.

6 Econometric Issues

Before proceeding to the estimation of equation (8), we must deal with three econometric issues. We use an instrumental variable approach to address endogeneity issues of control variables. One obvious candidate as an instrument is the lagged value. However, given our theoretical model, the lagged values themselves are endogenous, which would render them unsuitable as instruments. A common approach in the literature is to generate instruments as the weighted average of the explanatory variables in other countries.³² That is, for each element of X_{it} , it is possible to construct a weighted average for other countries. These weighted averages can be used directly as instruments for our model, and generate better instruments in the sense that they are more highly correlated with the endogenous variables (Brueckner 2003; Revelli 2005). As a result the standard errors tend to be smaller.

A second issue is that in practice, our tax rates are serially correlated, perhaps because unexpected changes in the tax system are likely to be costly to governments, either because such changes impose costs of adjustment on the private sector, or because such changes may be blocked at the political level by interest groups who stand to lose from the change. There may also be spatial correlation in the error terms. However, the lag formulation of equation (8) is justified both in terms of the theoretical analysis and on the basis of the strategic competition among the countries; and dominates any bias resulting from error components, (Devereux et al., 2007a). Subsequently, we present t-statistics based on clustered standard errors (Devereux et al., 2007) which are robust to both spatial correlation and serial correlation (Bertrand et al., 2004).

Working with countries within the European Union and controlling for an array of macro-economic variables does not ensure that most exogenous shocks that might result in spurious evidence of tax reaction functions are accounted for. This is a third issue in our analysis. Thus, we include country-specific fixed effects to capture shocks which are not common to all countries. The model is thus estimated both with and without year country effects. As a robustness

³²In fact, although the presented theory of tax competition treats taxes as the outcome of a game in which governments choose their taxes simultaneously, in practice fiscal policy takes time to design and implement and it is likely that governments choose their tax variables based on the observed past choices of rival governments rather than the anticipated ones. For these reasons, it is not the contemporaneous, but the lagged values of the explanatory variables in the rival countries that are often included in estimated models (Goodspeed 2000, 2002).

check we have used these effects in different model specifications.

7 Estimation Results

The suggested specification is tested over two alternative groups of countries in Europe (European Union of 17 members³³ and European Union of 27 members³⁴ that covers the latest major expansion of EU). The suggested differentiation allows for estimating the impact of expansion of the union and adoption of euro at the existed and new members.

7.1 Adoption of Euro and EU entry

Equation (8) implies that if α and γ are zero there will be no type of neighboring effect. Without the terms $a_{it} \sum_{\substack{j=1 \\ j \neq i}}^J w_{ij} \tau_{jt}$ and $\gamma_{it} \sum_{\substack{j=1 \\ j \neq i}}^J s_{ij} \tau_{jt}$, equation (8) can be easily estimated provided that the error process shows no temporal correlations, so that the lagged τ_{it-1} is independent of the error process.

The results for such a model are presented in Table 1 and refer to the EU of 17 members. Model (1) presents OLS results of equation (8) without the variables that capture the potential impact of EU entry and adoption of Euro. This is the benchmark model, without the neighboring effects, which is augmented further in Models 2-7. Specifically, models (2) and (3) show both the effects of EU entry and Euro adoption separately. Models (4) and (5) present Fixed Effect (FE) and Random Effect (RE) results for the basic specification of the model with both effects of EU entry and Euro adoption included. Finally, Models (6) and (7) present fixed effect and random effect results for the augmented specification of the model which controls for various country and region characteristics.

Consistently with the results from the literature, we find that the marginal tax of corporate rates is a function of a number of economic (i.e., GDP) and social (i.e., population) characteristics. Table 1 highlights that both the adoption of the Euro and the entrance in the European Union impact on the magnitude and the direction of the corporate tax rates. However, there are both theoretical and empirical reasons that this is not the appropriate model

³³It refers to the case before the expansion of EU in 2004 and includes Switzerland and Norway.

³⁴The largest expansion to date of the European Union took place when the Union was extended by 10 member-states: Poland, Lithuania, Latvia, Estonia, the Czech Republic, Slovakia, Slovenia, Hungary, Malta and Cyprus. We excluded from our estimation Malta and Cyprus due to data limitations

specification. First, our theoretical model suggests that other member countries' taxes should play a role. Second, the initial equation fails the test of over-identifying restrictions, and there is evidence of severe serial correlation. Moulton (1986) argued that estimation of an equation like (8) by ordinary least squares is likely to lead to downward bias in the standard errors of the coefficients of the explanatory variables.

We address each of these problems in turn. First, because taxes change only infrequently, we add a neighboring (spatially and economically defined) lagged dependent variable (refer to Table 2 and Table 3). As it is well known, temporally lagged dependent variable is correlated with the fixed effects, and thus treating it as exogenous may lead to biased estimates. So, we treat the temporally lagged dependent variable as endogenous and include the second lag in the instrument set. The lagged dependent variable is strongly significant, as might be expected, given only periodic changes in the nominal rate. Second, we correct (refer to Table 4) for potential serial correlation, at a following subsection, by using the Prais-Winsten estimation method.

Add here Table 1: Basic and Augmented specifications

A number of interesting observations can be made from results in Table 2. A first observation is that EU and Euro have different effects on corporate taxes. As shown by the corresponding estimates in models (2) to (9) the adoption of Euro has a negative and significant coefficient while the entrance in EU has a positive and significant impact in both defined groups of EU (17 and 27 countries). Moreover, even though it is difficult to discuss the exact direction and magnitude of the net effect from the entrance in the EU and the adoption of Euro currency, it seems that the latter generates higher elasticity responses than the former.

Recall from our theoretical discussion that the adoption of a common currency decreases the level of exchange rate uncertainty, and thereby leads to lower transaction costs and user-costs of capital. Consequently, it leads to more intense competition for capital. In addition, if entering a monetary union leads to a decrease in the levels of public debt, then adoption of a common currency will lead to lower net real interest rate and user-costs of capital. Thus, monetary integration can lead (via the user-cost-effect) to lower capital taxes. The above

empirical results regarding the impact of the adoption of Euro on corporate taxes suggest, indeed, that these two effects of monetary integration seem to dominate the effects of lower inflation and seignorage sharing discussed in our theoretical analysis.

Recall also from our theoretical discussion that entering the European Union may lead to more attractive investment conditions. These conditions may have to do with improved institutional quality and legislative framework, improved technological know-how e.t.c. In terms of our model, these could be captured by an increase in output-augmenting technologies. Consequently, entering the European Union can lead (via- the technology effect) to higher capital taxes. In addition, entering an economic union entails the abolition of tariffs. This, in turn, leads to higher user-costs of capital and (via the user-cost-effect) to higher capital taxes. The above empirical results regarding the impact of entering the EU suggest, then, that these two effects of economic integration seem to dominate the determination of corporate taxes when entering EU.

Notice that the effects of EU entry and Euro adoption exist parallel to the presence of strategic interaction in corporate tax setting among EU members. Comparing Model 1 with Models 2-6, we can see the implications of economic neighboring effects for the impact of European integration for EU17. Clearly, ignoring the economic neighboring effects leads to an underestimation of the aforementioned impact; a result that emphasizes the contribution of our work by taking explicit account of economic neighboring effects. Interestingly, also, the impact of European integration will be differentiated among the European countries. Countries with dissimilar socio-economic characteristics have different tax responses (see models 2 and 3). Therefore, the impact of countries with similar features (spatial and economic neighboring effects³⁵) corrects for any type of bias of the estimated results shown in Table 1.

Finally, it is worth drawing attention to the impact on the relevant estimates of the expansion of the Union (Models 7-9). Clearly, the impact of EU expansion corrects for any type of bias of the estimated results shown in Models 1-3 of Table 2. In fact, the significant coefficients of Euro and EU dummies for any categorization of GDP values highlight the fact that potential adoption of a common currency (or, a membership in the Union) do have a significant impact on the levels of corporate taxes.

³⁵We included in the estimated model all the corresponding temporally lagged spatial and economic formulations of the dependent variable but they are insignificant and do not alter the presented results.

The direct effect of the European Union has not been clearly identified in the literature. Most of the papers (Altshuler and Goodspeed, 2006; and Deveraux et al, 2007a) capture also the benefit of the membership in the European Union by presenting country dummies. The advantage of our work over the existing literature is that we account directly for the integrated geo-economic environment. The latter treatment is more informative given that we study a broader group of countries and we consider the impact of the expansion perspective of the union.

7.2 EU corporate taxation: spatial and economic dimensions

The geographical location and the concentration of economic activities, such as the existence of a core-periphery model, may lead to different optimal levels of taxation between regions (Kind et al., 2000; Baldwin and Krugman, 2004). In addition, differences in capital intensity of production may lead to specialized trade between the members of a union (Wilson, 1987) and thereby to different equilibrium levels of taxation. These are only some important determinants of non-cooperative capital taxes. Zodrow (2003) sought to assess which of the features of tax competition models fit best to the European Union and underlined that the basic difficulty is to assess the combined effects of these features.

The strategic interaction between countries has been the subject of recent literature. However, in this literature, the impact of economic and monetary integration and/or economic neighboring effects have not been accounted for. Here, by controlling for European integration, we find that both spatial and economic neighboring taxes affect the level of corporate taxation in European countries (see the corresponding coefficients of models 1 to 9 in Table 2). Spatial neighboring effects range for EU 17 from 0.19 to 0.76 (Models 1 to 6) and economic neighboring effects range from 0.51 to 0.87 (Models 1 to 6). These estimates suggest the presence of a race-to-bottom effect.

Gérard (2005) shows that the location decision of multinationals, as well as the choice between a foreign subsidiary and a foreign permanent establishment will severely impact on the total tax burden. However, his analysis, which is not based on a spatial econometric framework, faces the risk of underestimating the bias originated from spatial heterogeneity. The reason is, as it is well known from the economic literature, that taxes affect business location decisions. Spatial interactions have been the focus of a number of recent papers. Besley et al. (2001) use tax reaction functions for five different taxes in the OECD between 1965 and 1997, finding

interdependence in tax setting; a result in line with this paper. Karkalakos and Kotsogiannis (2007), explored provincial tax reaction functions for Canada and found positive neighboring spatial tax impacts at the level of provincial corporate setting; a result similar to the one presented in this analysis. Finally, Devereux, Lockwood and Redoano (2007a) and Redoano (2004) find similar to our evidence of strategic interaction in corporate tax setting for the OECD between 1992 and 2002 and for the EU-25 from 1980 to 1995 respectively.³⁶ However, our results are in contrast to the findings of Stewart and Webb (2006) who look at the evolution of corporate tax burdens - measured as corporate tax collected on GDP and on total taxes – in the OECD countries between 1950 and 1999. They find no evidence of a race-to-the-bottom effect. A potential explanation for the presented differences in magnitude and/or sign with the above works is the absence from their analysis of the impact of neighboring economic effects. In fact, the inclusion of economic weights contributes from a different perspective to the explanation of the existed spatial autocorrelation of capital taxes (compare Model 1 with Models 2-6 in Table 2).

The expansion of EU (Models 7, 8 and 9) results in higher spatial neighboring impact (0.74) and lower economic neighboring impact (0.16) for countries with high GDP values comparing to the initial group of EU (17 countries). A higher spatial impact in Model 8 denotes that neighboring countries with high GDP values play a more important role after the expansion than before it. The latter result is a significant contribution of this paper. Moreover, economic closeness (neighboring effect) implies a lower impact at the setting of corporate taxes for the EU of 27 than the EU of 17 countries. Interestingly, spatial estimates for neighboring countries with low GDP values do not affect the level of corporate taxes (Model 10 Table 2). The significant estimates of openness and neighboring economic weights indicate that as the union expands more corporations are located in EU given the attractiveness of a large unified market.

Add here Table 2. Spatial and Economic Criteria (Neighboring taxes)

³⁶Redoano (2004), using panel data from 1980 to 1995, found interdependency among EU members regarding both tax rates and government expenditures.

7.3 EU corporate taxation: other determinants

Inflation and population effects have a positive impact on corporate taxes (Table 2). A possible reason for these, after recalling our discussion of the theoretical model, is that an increase in these variables leads to higher relative demand for public good.

Debt has also a positive impact on capital taxes. Possible reason for this is the associated negative effect of public debt on capital supply. Note also that unemployment and wage have no impact at the capital tax rate competition in European Union.³⁷

Furthermore, openness has an insignificant impact on capital taxes for EU17. This is not in line with the findings of Slemrod (2004) of a negative association between measures of openness and statutory rates. However, Altshuler and Goodspeed T. (2006) find that European countries have become over time less intensely competitive among themselves; a concluding argument that supports our findings. Our result in question is also consistent with the models of tax setting along the lines developed by Besley and Rosen (1998) and Devereux, Lockwood and Redoano (2007 a,b). Notice, however, that enlargement of the euro-zone implies a positive and significant link between openness and capital taxes.

Finally, market capitalization refers to the number of listed companies (as a % of GDP) in the economy. Note that the corresponding elasticity ranges from -0.03 (for high GDP countries) to -0.17 (for similar degree of market capitalization countries) for EU 17 (Models 1 to 6), where the expansion of EU resulted at a smaller spread from -0.04 to -0.12 (Models 7 to 9). Therefore, the higher the number of the listed companies, the lower the corporate tax rates are. One could argue that market capitalization can be thought of as a measure of capital-intensity of production. If one takes this view, then the above result can be thought of echoing the theoretical result in Wilson (1987).

7.4 Robustness

Beside the inverse distance-based criterion we used a number of alternative spatial weight specifications to examine the robustness of results. Actually, we employed k-neighbors criteria (with $k = 6$ or $k = 8$), and specific distance zone criteria (with $d = 300$ km or $d = 1000$ km) as suggested by Bottazzi and Peri (2003). The results do not vary significantly. Moreover, the F test in the first stage of the estimation tests the null hypothesis of whether the instruments

³⁷Due to space limitation the relevant estimations are omitted from Table 2.

are not correlated with the endogenous variables. Given the outcome of Table 2, we reject the null hypothesis of no correlation.

Furthermore, Table 3 presents alternative models to examine the robustness of the results. The degree of differentiation refers to the inclusion of interaction terms to the models described in Table 2. We use a number of interaction components (i.e., $\text{inflation}^*\text{euro}$ and $\text{openness}^*\text{euro}$) to control for fiscal or market effects. It has been well established (Revelli, 2005) that the intuition behind conditional hypotheses is captured quite well by multiplicative interaction models. Interestingly, the coefficients of $\text{inflation}^*\text{euro}$ and $\text{Openness}^*\text{euro}$ are significant only for high GDP values (1st and 8th model, Table 3). This is a significant finding of this analysis, due to the fact that previous studies do not take into account economic neighboring effects. Moreover, note that the EU dummy remains significant, after using most of the economic criteria. Countries with high GDP values decrease (by 0.05%) the corporate tax rates should inflation is increased and additionally we control for the adoption of Euro. Additionally, countries with high GDP values increase (by 1.59%) the corporate tax rates should the degree of openness is increased and additionally we control for the adoption of Euro. Those are the countries that are mostly benefited since they represent the major trading countries in the union. The pattern of the remaining coefficients remains similar to the one at Table 2. Finally, the expanded version of the Union (EU 27) follows a similar pattern of results with the initial specification presented at Table 2. It is clear that economic weights drive the existence of neighboring impact and they are originated from the initial group of EU members.

Add here Table 3: Robustness check

7.5 Temporal and spatial dependence

In this section of the paper, the errors are also assumed to display serial correlation, and therefore the Prais-Winsten estimation is used with PCSE (PW-PCSE). And since T is larger than N , although not substantially larger, the FGLS estimates are also reported in Table 4. Economic weights are defined based on the GDP criterion and market capitalization, where spatial weights are based on the inverse distance criterion. For this study, with 17 countries and 30 time periods, the bias is anticipated to be considerably smaller than for the typical panel data with a large number of cross sections and usually less than 10 time periods. So, the FGLS and PW-PCSE estimates may still perform reasonably well here in the presence of the

lagged dependant variable.

It is well known that generally, strategic interaction can be generated by either tax competition or yardstick competition (Besley and Smart, 2003). The consistent performance of neighboring spatial and economic weights suggests that tax competition is at work. Allowing for serial correlations at the errors we examine the significance of yardstick competition in our model. Table 4 verifies the robustness of our results towards that direction, since most of the presented estimates have great similarities with the one at Table 2. Models 1 and 2 do not take into account temporally lagged corporate taxes but Models 3 and 4 include them. Models 1 to 4 use economic weights based on GDP similarity index, where Models 5 and 6 define economic weights based on market capitalization similarity index.

Add here Table 4. Temporal dependence

8 Concluding Remarks

There are a number of theoretical reasons why corporate taxes may depend on the corporate taxes in proximate countries on both geographic and economic grounds. Such spatial and economic interdependences have been largely ignored by the empirical literature with only a couple recent papers accounting for such issues in their estimation. This paper conducts a more general examination of spatial and economic interactions in empirical tax models using data from the European Union.

We find that estimated relationships of traditional determinants of corporate tax setting are robust to inclusion of terms that capture spatial and economic interdependences for the EU17. Moreover, we find that the estimated spatial and economic interdependences are quite sensitive to the sample of countries one examines. In particular, the geographic scope of the sample is quite important in trying to separate evidence supporting different motivations for equilibrium tax levels. The expansion of EU (EU27) results at a lower impact of spatial determinants, while emphasizing the impact of economic one.

Omitted variable bias from not modeling spatial and economic interdependence is apparently quite significant in these cross-country corporate-tax estimations across the variety of EU definitions we explore. This point is particularly applicable to the few previous studies of

spatial effects in empirical corporate tax patterns, as ours is the first to include both spatial and economic effects, and control explicitly for the effects of both economic and monetary integration in Europe.

Furthermore, our results highlight that economic and monetary integration have a significant impact on corporate taxes in Europe. The estimates of monetary (Euro dummy) and political (EU dummy) determinants of corporate taxes are in fact very robust to changing the sample of EU countries. Specifically, we find that economic integration has led to higher taxes, while monetary integration has led to lower taxes. Our theoretical model suggests that these effects could mainly be due to the associated (a) increase in the average technological quality and decrease in public indebtedness and (b) the effects on the user-costs of capital of lower transaction costs and tariffs. Importantly, our theoretical and empirical results indicate that the recent movements in capital taxes in EU could be attributed to the introduction of the Euro. As capital movements have further been enhanced and a unified monetary base has been introduced, through euro currency, more countries have been engaged in tax competition. This intensified competition seems to be a major determinant of the reduction in average tax rates over the period and the country samples considered.

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10 Appendix A

By iterating forward the consumer's budget constraint and using the transversality condition $\lim_{v \rightarrow \infty} \frac{(B_{jt+1+v} + M_{jt+1+v})}{\Pi_{z=1}^v (1 + \rho_{t+z})} = 0$ we derive the consumer's intertemporal budget constraint

$$\sum_{v=0}^{\infty} \frac{(1 + \beta_{jt+v})C_{jt+v}^i + (\pi_{jt+v} + \rho_{t+v})M_{jt+v}^i}{\Pi_{z=1}^v (1 + \rho_{t+z})} = (1 + \rho_t)(M_{jt}^i + B_{jt}^i) + \sum_{v=0}^{\infty} \frac{\sigma_{jt+v}^i (1 + \beta_{jt+v}) A_{jt+v} \Pi_j [r_{jt+v}]}{\Pi_{z=1}^v (1 + \rho_{t+z})},$$

where $\Pi_{z=1}^v (1 + \rho_{t+z}) \equiv (1 + \rho_{t+1}) \dots (1 + \rho_{t+v})$ is the compounded real rate of return to savings, with the convention that $\Pi_{z=1}^0 (1 + \rho_{t+z}) \equiv 1$.

Period- t consumption and real money balances are then part of the solution of the system of the consumer's intertemporal budget constraint and, for any $v = 0, \dots, \infty$, of the first order conditions (f.o.c.'s) with respect to B_{jt+v+1}^i and M_{jt+v+1}^i . After some straightforward manipulations, the latter can be written as:

$$\begin{aligned} U_{jC}^i [C_{jt+v}^i, M_{jt+v+1}^i] &= \frac{(1 + \beta_{jt+v})(1 + \rho_{t+v+1})\theta_j^i}{1 + \beta_{jt+v+1}} U_{jC}^i [C_{jt+v+1}^i, M_{jt+v+2}^i], \\ \frac{U_{jC}^i [C_{jt+v}^i, M_{jt+v+1}^i]}{U_{jM}^i [C_{jt+v}^i, M_{jt+v+1}^i]} &= \frac{(1 + \beta_{jt+v})(1 + i_{jt+v+1})}{i_{jt+v+1}}, \end{aligned}$$

where $i_{jt+v+1} = \frac{1 + \rho_{t+v+1}}{1 - \pi_{jt+v+1}} - 1$ is the nominal interest rate in country j

So, from the f.o.c. with respect to M_{jt+v+1}^i , money holdings are such that the marginal rate of substitution between real money and consumption equals the relative price between consumption and real money.³⁸ Assuming that $\frac{U_{jC}^i [C_{jt+v}^i, M_{jt+v+1}^i]}{U_{jM}^i [C_{jt+v}^i, M_{jt+v+1}^i]}$ is strictly increasing with M_{jt+v+1}^i , we have that the latter is decreasing with the nominal interest rate. Assuming also that $\frac{U_{jC}^i [C_{jt+v}^i, M_{jt+v+1}^i]}{U_{jM}^i [C_{jt+v}^i, M_{jt+v+1}^i]}$ is strictly decreasing with C_{jt+v}^i , we have that real money balances increase with consumption. Let $\tilde{M}_j^i [C_{jt+v}^i, \frac{i_{jt+v+1}}{(1 + \beta_{jt+v})(1 + i_{jt+v+1})}]$ be the resulting demand for money in period $t + v$, as an increasing function of consumption and a decreasing function of the relative price of money.

Using the money demand function $\tilde{M}_j^i [\cdot]$ in the f.o.c. with respect to B_{jt+v+1}^i we have

$$\begin{aligned} U_{jC}^i [C_{jt+v}^i, \tilde{M}_j^i [C_{jt+v}^i, \frac{i_{jt+v+1}}{(1 + \beta_{jt+v})(1 + i_{jt+v+1})}]] &= \\ \frac{(1 + \beta_{jt+v})(1 + \rho_{t+v+1})\theta_j^i}{1 + \beta_{jt+v+1}} U_{jC}^i [C_{jt+v+1}^i, \tilde{M}_j^i [C_{jt+v+1}^i, \frac{i_{jt+v+2}}{(1 + \beta_{jt+v+1})(1 + i_{jt+v+2})}]] & \end{aligned}$$

³⁸Note from the intertemporal budget constraint, that $\frac{\pi_{t+v+1} + \rho_{t+v+1}}{1 + \rho_{t+v+1}} = \frac{i_{t+v+1}}{1 + i_{t+v+1}}$ can be thought of as the price of real money holdings, M_{t+v+1} , relative to consumption C_{t+v} .

Backward iteration of this implies that, for any $v = 1, \dots, \infty$, C_{jt+v}^i is given by a function $\tilde{C}_j^i[C_{jt}^i, 1 + \beta_{jt}, 1 + \beta_{jt+v}, \frac{i_{jt+v+1}}{1+i_{jt+v+1}}, \frac{i_{jt+1}}{1+i_{jt+1}}, \theta_j^v \Pi_{z=1}^v(1 + \rho_{t+z})]$, which is implicitly determined by

$$\begin{aligned} & \frac{U_{jC}^i[C_{jt+v}^i, \tilde{M}_j^i[C_{jt+v}^i, \frac{i_{jt+v+1}}{(1+\beta_{jt+v})(1+i_{jt+v+1})}]]}{U_{jC}^i[C_{jt}^i, \tilde{M}_j^i[C_{jt}^i, \frac{i_{jt+1}}{(1+\beta_{jt})(1+i_{jt+1})}]]} = \\ & \left(\frac{1 + \beta_{jt+v}}{(1 + \beta_{jt+v-1})(1 + \rho_{t+v})\theta_j^i} \right) \dots \left(\frac{1 + \beta_{jt+1}}{(1 + \beta_{jt})(1 + \rho_{t+1})\theta_j^i} \right) = \\ & \frac{1 + \beta_{jt+v}}{(1 + \beta_{jt})\theta_j^v \Pi_{z=1}^v(1 + \rho_{t+z})}. \end{aligned}$$

Assuming that $U_{jCC}^i \frac{\partial[U_{jC}^i/U_{jM}^i]}{\partial M} < U_{jCM}^i \frac{\partial[U_{jC}^i/U_{jM}^i]}{\partial C}$ we have that $\tilde{C}_j^i[C_{jt}^i, \bullet]$ is strictly increasing with C_{jt}^i . Thus, if C_{jt}^i is a normal good, so is C_{jt+1}^i for any $v = 1, \dots, \infty$. Therefore, we also have that $\tilde{C}_j^i[\bullet]$ is strictly increasing with $\theta_j^v \Pi_{z=1}^v(1 + \rho_{t+j})$.

$\tilde{C}_j^i[\bullet]$, $\tilde{M}_j^i[\bullet]$ and the intertemporal budget constraint give, after recalling the definition of the nominal interest rate, demands for consumption and real money balances in any period $t, t + 1, \dots, \infty$, as a function of all prices, policies and technological parameters from period t and onwards, and as a function of period- $t - 1$ bonds and money holdings, B_{jt}^i and M_{jt}^i . As part of this solution, we clearly have demand functions for period t : $C_{jt}^i[\rho_t, r_{jt}, x_{jt}, s_{jt}^i, A_{jt}]$ and $M_{jt+1}^i[\rho_t, r_{jt}, x_{jt}, s_{jt}^i, A_{jt}]$, as described in Section 2. In fact, note that, given the above assumptions, an increase in period- t intertemporal income, $(1 + \rho_t)(M_{jt}^i + B_{jt}^i) + \sum_{v=0}^{\infty} \frac{\sigma_{jt+v}^i(1+\beta_{jt+v})A_{jt+v}\Pi_j[r_{jt+v}]}{\Pi_{z=1}^v(1+\rho_{t+z})}$, will increase, all other things equal, C_{jt}^i and thereby C_{jt+v}^i and M_{jt+v}^i for any $v = 1, \dots, \infty$.

Demand for real bonds in period t , $B_{jt+1}^i[\rho_t, r_{jt}, x_{jt}, s_{jt}^i, A_{jt}]$, in turn, is given by utilizing the period- t private budget constraint:

$$\begin{aligned} & B_{jt+1}^i[\rho_t, r_{jt}, x_{jt}, s_{jt}^i, A_{jt}, \mu_{jt}] = \\ & (1 + \rho_t)B_{jt}^i + (1 - \pi_{jt})M_{jt}^i \\ & + \sigma_{jt}^i(1 + \beta_{jt})A_{jt}\Pi_j[r_{jt}] \\ & - M_{jt+1}^i[\rho_t, r_{jt}, x_{jt}, s_{jt}^i, A_{jt}] - (1 + \beta_{jt})C_{jt}^i[\rho_t, r_{jt}, x_{jt}, s_{jt}^i, A_{jt}]. \end{aligned}$$

11 Appendix B

Let, after suppressing the obvious dependence on $A_{jt+1}, \mu_{jt+1}, a_{jt+1}$ and $\{\rho_{t+2}, \rho_{t+3}, \dots\}$,

$$\hat{W}_{jt+1}[Q_{t+1}, \rho_{t+1}, s_{jt+1}^1, \dots, s_{jt+1}^{N_j}, \kappa_{jt+1}] \equiv \max_{\tau, x, d} \sum_i V_{jt+1}^i[\rho_{t+1}, r_{jt+1}, x, s_{jt+1}^i, A_{jt+1}] H_j^i[G_{jt+1}] + \theta_j^i W_{jt+2}[Q_{t+2}, \rho_{t+2}]$$

subject to $Q_{jt+2} = Q_{jt+2}[Q_{jt+1}, r_{jt+1}, x, d, \rho_{t+1}]$, for any j

$$\begin{aligned} G_{jt+1} &= \tau K_j[r_{jt+1}] + d - (1 + \rho_{t+1}) D_{jt+1} \\ &+ a_{jt+1}(M_{jt+2} - (1 - \pi) M_{jt+1}) + \kappa_{jt+1} \\ &+ \beta \sum_i C_{jt+1}^i[\rho_{t+1}, r_{jt+1}, x, s_{jt+1}^i, A_{jt+1}] \end{aligned}$$

$$- \beta (A_{jt+1} F_j[K_j[r_{jt+1}]] + (1 - \delta_{jt+1}) K_j[r_{jt+1}]),$$

$\pi = \pi_{t+1}$ under monetary union, and

$$\begin{aligned} M_{jt+2} &\equiv \sum_{i=1}^{N_j} M_{jt+2}^i[\rho_{t+1}, r_{jt+1}, x, s_{jt+1}^i, A_{jt+1}], \\ r_{jt+1} &\equiv \frac{\rho_{t+1} + \delta_{jt+1} + \mu_{jt+1} + \tau - \beta(1 - \delta_{jt+1})}{A_{jt+1}(1 + \beta)}. \end{aligned}$$

Note, after recalling also the definition of s_{jt+1}^i , that from the system of the above optimisation problem for *every* country one derives the MPE strategies of every country j , for (a) capital taxes, denoted by $\tilde{T}_{jt+1}[Q_{t+1}, \rho_{t+1}]$, (b) import taxes and inflation rate, denoted and summarized by $\tilde{x}_{jt+1}[Q_{t+1}, \rho_{t+1}]$, and (c) received share of foreign seignorage, denoted by $\kappa_{jt+1}[Q_{t+1}, \rho_{t+1}]$, (d) public good, denoted by $G_{jt+1}[Q_{t+1}, \rho_{t+1}]$, and (e) user-cost of capital, denoted by $\tilde{r}_{jt+1}[Q_{t+1}, \rho_{t+1}]$.

Note that $W_{jt+1}[Q_{t+1}, \rho_{t+1}] = \hat{W}_{jt+1}[Q_{jt+1}, \rho_{t+1}, s_{jt+1}^1, \dots, s_{jt+1}^{N_j}, \kappa_{jt+1}[Q_{t+1}, \rho_{t+1}]]$.

12 Appendix C

In the f.o.c.,

$$\begin{aligned} \Phi_{jt} &\equiv \frac{1}{K_j[r_{jt}] A_{jt} (1 + \beta_{jt}) \sum_{i=1}^{N_j} \sigma_{jt}^i U_{jC}^i[C_{jt}^i, M_{jt+1}^i] H_j^i[G_{jt}]} \times \\ &\left\{ \sum_{i=1}^{N_j} \sum_{\zeta_{jt+1}^i \in \{M_{jt+1}^i, B_{jt+1}^i\}} \frac{\theta_j^i \partial W_{jt+1}[Q_{t+1}, \rho_{t+1}]}{\partial \zeta_{jt+1}^i} \frac{\partial C_{jt+1}^i[Q_{jt}, r_{jt}, x_{jt}, d_{jt}, \rho_t]}{\partial r_{jt}} \right\}. \end{aligned}$$

This is a measure of the marginal effect of the capital tax on future welfare relative to current national capital.

In addition,

$$\begin{aligned}
R_{jt} &\equiv \frac{1}{K_j[r_{jt}]A_{jt}(1 + \beta_{jt})} \left\{ a_{jt} \sum_{i=1}^{N_j} \frac{\partial M_{jt+1}^i[\bullet]}{\partial r_{jt}} \right. \\
&\quad \left. + \beta_{jt} \sum_{i=1}^{N_j} \frac{\partial C_{jt}^i[\bullet]}{\partial r_{jt}} \right. \\
&\quad \left. - \beta_{jt}(A_{jt}r_{jt} + (1 - \delta_{jt}))K'_j[r_{jt}] \right\}.
\end{aligned}$$

Moreover,

$$\lambda_{jt} \equiv \frac{\sum_{i=1}^{N_j} U_j^i[C_{jt}^i, M_{jt+1}^i]H_j^{i'}[G_{jt}]}{\sum_{i=1}^{N_j} \sigma_{jt}^i U_{jC}^i[C_{jt}^i, M_{jt+1}^i]H_j^i[G_{jt}]} > 0.$$

13 Appendix D

Consider first the total differential R_{jt} for given capital tax. We have

$$\begin{aligned}
&K_{jt}A_{jt}(1 + \beta_{jt})dR_{jt} = \\
&-\{R_{jt}K'_{jt}A_{jt}(1 + \beta_{jt}) - \sum_{i=1}^{N_j} (\beta_{jt} \frac{\partial^2 C_{jt}^i[\bullet]}{\partial r_{jt}^2} + a_{jt} \frac{\partial^2 M_{jt+1}^i[\bullet]}{\partial r_{jt}^2}) \\
&\quad + \beta_{jt}(A_{jt}K'_{jt} + (A_{jt}r_{jt} + (1 - \delta_{jt}))K''_{jt})\}dr_{jt} \\
&+ \left\{ \sum_{i=1}^{N_j} \frac{\partial C_{jt}^i[\bullet]}{\partial r_{jt}} + \sum_{i=1}^{N_j} (\beta_{jt} \frac{\partial^2 C_{jt}^i[\bullet]}{\partial r_{jt} \partial \beta_{jt}} + a_{jt} \frac{\partial^2 M_{jt+1}^i[\bullet]}{\partial r_{jt} \partial \beta_{jt}}) \right. \\
&\quad \left. - (A_{jt}r_{jt} + (1 - \delta_{jt}))K'_{jt} - A_{jt}K_{jt}R_{jt} \right\}d\beta_{jt} \\
&+ \left\{ -\beta_{jt}r_{jt}K'_{jt} + \sum_{i=1}^{N_j} (\beta_{jt} \frac{\partial^2 C_{jt}^i[\bullet]}{\partial r_{jt} \partial A_{jt}} + a_{jt} \frac{\partial^2 M_{jt+1}^i[\bullet]}{\partial r_{jt} \partial A_{jt}}) - K_{jt}R_{jt}(1 + \beta_{jt}) \right\}dA_{jt} \\
&\quad + \sum_{\chi_{jt} \in \{\rho_{jt}, \pi_{jt}\}} \sum_i (\beta_{jt} \frac{\partial^2 C_{jt}^i[\bullet]}{\partial r_{jt} \partial \chi_{jt}} + a_{jt} \frac{\partial^2 M_{jt+1}^i[\bullet]}{\partial r_{jt} \partial \chi_{jt}})d\chi_{jt} \\
&\quad + \sum_{i=1}^{N_j} \sum_{\chi_{jt}^i \in \{M_{jt}^i, B_{jt}^i\}} (\beta_{jt} \frac{\partial^2 C_{jt}^i[\bullet]}{\partial r_{jt} \partial \chi_{jt}^i} + \frac{a_{jt}}{K_{jt}} \frac{\partial^2 M_{jt+1}^i[\bullet]}{\partial r_{jt} \partial \chi_{jt}^i})d\chi_{jt}^i \\
&\quad + \sum_{i=1}^{N_j} \frac{\partial M_{jt+1}^i[\bullet]}{\partial r_{jt}} da_{jt}
\end{aligned} \tag{10}$$

The first term above captures the fact that the capital-tax-induced net increase in revenues from import taxes and seignorage, R_{jt} , depends on the user-cost of capital, r_{jt} , in two ways. The first is due to the fact that R_{jt} is expressed as a proportion of the current capital. Since the latter is decreasing with the capital's user-cost, we have that an increase in the latter leads to an increase in R_{jt} , all other things equal. Second, the user-cost of capital affects the capital-tax-induced change in seignorage and tariff revenues. This effect is ambiguous.

For given capital's user-cost, R_{jt} is affected by a change in the tariff, β_{jt} , in four ways. This is captured in the second term above. First, an increase in the tariff raises the capital-tax-induced decrease in tariff revenues that follows from the negative effect of the capital tax on consumption. This pushes to a lower R_{jt} , all other things equal. Second, an increase in the tariff affects the price of consumption and hence the capital-tax-induced decrease in money holdings and consumption. The former, in turn, affects seignorage, while the latter affects revenues from import taxes. This effect is ambiguous and it depends on the specifics of consumers' utility. Third, an increase in the tariff increases the capital-tax-induced increase in tariff revenues that follows from the negative effect of the capital tax on production. Fourth, an increase in the tariff reduces the positive impact of the capital tax on the user-cost of capital, and thereby the capital-tax-induced net increase in the revenues from seignorage and import taxes. This effect has the opposite sign of R_{jt} , which, recall, is ambiguous.

For given capital's user-cost, R_{jt} is affected by a change in the output-augmenting technology, A_{jt} , in three ways. This is captured in the third term above. First, an increase in the technology raises the capital-tax-induced increase in tariff revenues that follows from the negative effect of the capital tax on production. This pushes to a higher R_{jt} , all other things equal. Second, an increase in technology affects positively the income from the fixed factor and hence the capital-tax-induced change in money holdings and consumption. As in the case of the tariff, these affect the revenues from seignorage and import taxes. This effect is also ambiguous and it depends on the particulars of consumers' utility. Third, an improvement in technology reduces the positive impact of the capital tax on the user-cost of capital, and thereby the capital-tax-induced net increase in the revenues from seignorage and import taxes. This effect has the opposite sign of R_{jt} , which is ambiguous.

For given capital's user-cost, R_{jt} depends also on the net real interest rate, ρ_{jt} . Specifically, an increase in the net real interest rate affects positively the returns to past bond holdings, and hence the capital-tax-induced change in money holdings and consumption. This has an ambiguous effect on R_{jt} . Similarly, for inflation, π_{jt} , and pre-determined money, M_{jt}^i , and bond holdings, B_{jt}^i . These are captured by the fourth and fifth terms above.

Finally, we have that R_{jt} depends on the seignorage share a_{jt} . This is captured by the sixth term above. Under normality, this effect is negative. The reason is that a higher share leads to a higher capital-tax-induced decrease in demand for money and hence seignorage.

We turn to the public-good valuation λ_{jt} . Totally differentiating for given capital tax

leads to

$$d\lambda_{jt} = \frac{\partial \lambda_{jt}}{\partial G_{jt}} dG_{jt} + \sum_{i=1}^{N_j} \frac{\partial \lambda_{jt}}{\partial C_{jt}^i} dC_{jt}^i + \sum_{i=1}^{N_j} \frac{\partial \lambda_{jt}}{\partial M_{jt}^i} dM_{jt}^i. \quad (11)$$

After noting that $\frac{\partial \lambda_{jt}}{\partial G_{jt}} < 0$, we have that an increase in public good provision leads to a lower valuation for public good. Similarly, due to $\frac{\partial \lambda_{jt}}{\partial C_{jt}^i} > 0$, an increase in consumption leads to a higher valuation for public good. However, note that the sign of $\frac{\partial \lambda_{jt}}{\partial M_{jt}^i}$ cannot be ensured unless further restrictions are imposed on preferences.

Of course, public good provision, consumption and money holdings are themselves functions of the user-cost of capital, the tax on imports, technology, transaction costs and other important determinants. To gain further understanding note, after totally differentiating the government's budget constraint for given capital tax, and using $\sum_i C_{jt}^i = C_{jt}$ and $\sum_i M_{jt}^i = M_{jt}$, that

$$\begin{aligned} dG_{jt} = & a_{jt} \sum_{i=1}^{N_j} dM_{jt+1}^i + \beta_{jt} \sum_{i=1}^{N_j} dC_{jt}^i \\ & + \{\tau K'_{jt} - \beta_{jt}(A_{jt}r_{jt} + (1 - \delta_{jt}))K'_{jt}\} dr_{jt} \\ & + \left\{ \sum_i C_{jt}^i - Y_{jt} \right\} d\beta_{jt} \\ & - \beta_{jt} F[K_{jt}] dA_{jt} \\ & + \left\{ \sum_i (M_{jt+1}^i - (1 - \pi_{jt})M_{jt}^i) \right\} da_{jt} + d\kappa_{jt} \\ & - a_{jt}(1 - \pi_{jt}) dM_{jt} + a_{jt}M_{jt} d\pi_{jt} \\ & + dD_{t+1} - (1 + \rho_t) dD_{jt} - D_{jt} d\rho_t. \end{aligned} \quad (12)$$

Thus, all other things equal, an increase in demand for money and/or consumption increases the public good. These are captured by the first two terms, respectively. An increase in past holdings of money, outstanding debt and the net real interest rate reduce current public good provision. These are captured by the eleventh and twelfth terms above, respectively. On the other hand, an increase in inflation and in issued public debt raise public good provision - see the ninth and tenth terms above, respectively.

Furthermore, we have that an increase in the capital's user-cost, r_{jt} , has three effects on public good provision. This is captured by the third term above. The first effect is negative, and arises from the fact that a higher user-cost of capital leads to lower capital and thereby revenues from capital, for given taxes. The second effect is positive, and arises from the negative effect of lower capital on output, and the positive thereby effect on imports and hence tariff revenues.

An increase in the tariff, β_{jt} , leads unambiguously to higher (resp. lower) public revenues for an importing (resp. exporting) country. This is captured by the fourth term above.

An improvement in output-augmenting technology, A_{jt} , has a negative effect on public revenues, captured by the fifth term above. It arises from the positive effect of better technology on output, and the negative thereby effect on imports and hence tariff revenues.

The sixth and seventh terms above capture, respectively, the effects on public revenues of a change in the seignorage share, a_{jt} , and the transfer of foreign seignorage, κ_{jt} . These effects are important for a country that enters a monetary union. Clearly, the net revenue effect is ambiguous. A decrease in the seignorage share a_{jt} lowers revenues from national seignorage, while an increase in the appropriated foreign seignorage raises revenues, and hence public good provision.

We now turn to consumption and demand for real money balances, which influence public revenues and the public good valuation λ_{jt} , and hence the public-good-valuation effect. After using the optimal consumption functions, we have that

$$\begin{aligned} dC_{jt}^i &= \frac{\partial C_{jt}^i[\bullet]}{\partial \beta_{jt}} d\beta_{jt} + \frac{\partial C_{jt}^i[\bullet]}{\partial r_{jt}} dr_{jt} + \frac{\partial C_{jt}^i[\bullet]}{\partial A_{jt}} dA_{jt} \\ &+ \frac{\partial C_{jt}^i[\bullet]}{\partial \rho_t} d\rho_t + \frac{\partial C_{jt}^i[\bullet]}{\partial \pi_t} d\pi_t + \frac{\partial C_{jt}^i[\bullet]}{\partial M_{jt}^i} dM_{jt}^i + \frac{\partial C_{jt}^i[\bullet]}{\partial B_{jt}^i} dB_{jt}^i, \end{aligned} \quad (13)$$

and, similarly, from the optimal money demand functions,

$$\begin{aligned} dM_{jt+1}^i &= \frac{\partial M_{jt+1}^i[\bullet]}{\partial \beta_{jt}} d\beta_{jt} + \frac{\partial M_{jt+1}^i[\bullet]}{\partial r_{jt}} dr_{jt} + \frac{\partial M_{jt+1}^i[\bullet]}{\partial A_{jt}} dA_{jt} \\ &+ \frac{\partial M_{jt+1}^i[\bullet]}{\partial \rho_t} d\rho_t + \frac{\partial M_{jt+1}^i[\bullet]}{\partial \pi_t} d\pi_t + \frac{\partial M_{jt+1}^i[\bullet]}{\partial M_{jt}^i} dM_{jt}^i + \frac{\partial M_{jt+1}^i[\bullet]}{\partial B_{jt}^i} dB_{jt}^i. \end{aligned} \quad (14)$$

We have that a decrease in current inflation, or an increase past holdings of bonds and money or in the current net interest rate raises current income from past savings. Moreover, an improvement in technology or a reduction in the user-cost of capital increase rents. All these changes lead to higher income and hence, by normality, to higher consumption and demand for real money. These are captured, respectively, by the fifth, seventh, sixth, fourth, third and second terms in the above equations, where $\frac{\partial C_{jt}^i[\bullet]}{\partial \chi_{jt}} > 0$ and $\frac{\partial M_{jt+1}^i[\bullet]}{\partial \chi_{jt}} > 0$ for $\chi_{jt} \in \{A_{jt}, M_{jt}^i, B_{jt}^i, \rho_t\}$, while $\frac{\partial C_{jt}^i[\bullet]}{\partial \chi_{jt}} < 0$ and $\frac{\partial M_{jt+1}^i[\bullet]}{\partial \chi_{jt}} < 0$ for $\chi_{jt} \in \{r_{jt}, \pi_{jt}\}$. Furthermore, we have that the effects of an increase in the tariff on consumption and money demand are ambiguous. The reason is that a higher tariff increases the price of consumption, while it increases the income from the fixed factor.

Let us now turn to the dependence of the capital's user-cost on transaction costs, the tariff, technology, and net real interest rate. We have, for given capital tax, from (2) that

$$dr_{jt} = \frac{1}{A_{jt}(1 + \beta_{jt})} \{d\mu_{jt} - (r_{jt}A_{jt} + 1 - \delta_{jt})d\beta_{jt} - r_{jt}(1 + \beta_{jt})dA_{jt} + d\rho_t\} \quad (15)$$

Thus, a higher net real interest rate and/or transaction costs will increase the user-cost of capital, while a higher tariff and/or an improvement in technology will lead to a lower user-cost of capital.

Notice now that for many of the above determinants of capital taxes, changes in the net real interest rate are important. Given that the net real interest rate is itself endogenously determined in equilibrium, we turn to its total differential, for given domestic (i.e. country- j) capital tax. By making use of the capital-market-clearing condition (3) and the definition of the capital's user-cost (2), we have

$$\begin{aligned} \left(\sum_{v=1}^J \frac{K'_{vt}}{A_{vt}(1 + \beta_{vt})}\right)d\rho_t &= d\bar{K}_t - \sum_{v=1}^J \frac{K'_{vt}}{A_{vt}(1 + \beta_{vt})}d\mu_{vt} \\ + \sum_{v=1}^J \frac{K'_{vt}}{A_{vt}(1 + \beta_{vt})} &((r_{vt}A_{vt} + 1 - \delta_{vt})d\beta_{vt} + r_{vt}(1 + \beta_{vt})dA_{vt}) \\ &- \sum_{\substack{v=1 \\ v \neq j}}^J \frac{K'_{vt}}{A_{vt}(1 + \beta_{vt})}d\tau_{vt}. \end{aligned} \quad (16)$$

Thus, higher supply of capital, \bar{K}_t , lead to a lower net real interest rate. Also, lower transaction costs, higher tariffs and improvements in technology across regions increase regional demands for capital, and hence lead to a higher net real interest rate. Furthermore, higher foreign capital taxes lead to lower demand for capital abroad and thereby a decrease in the net real interest rate. It should be emphasized here that foreign capital taxes, tariffs, capital transaction costs, output-augmenting technologies and supplies of capital affect the user-costs of capital *across* regions through their impact on the common net real interest rate. In fact, combining (15) and (16) we have

$$\begin{aligned}
A_{jt}(1 + \beta_{jt})dr_{jt} &= \frac{1}{\sum_{v=1}^J \frac{K'_{vt}}{A_{vt}(1+\beta_{vt})}} d\bar{K}_t \\
&+ (1 - k_{jt})d\mu_{jt} \\
&- (r_{jt}A_{jt} + 1 - \delta_{jt})(1 - k_{jt})d\beta_{jt} \\
&- r_{jt}(1 + \beta_{jt})(1 - k_{jt})dA_{jt} \\
&+ \sum_{\substack{v=1 \\ v \neq j}}^J k_{vt}((r_{vt}A_{vt} + 1 - \delta_{vt})d\beta_{vt} + r_{vt}(1 + \beta_{vt})dA_{vt} - d\mu_{vt} - d\tau_{vt}),
\end{aligned} \tag{17}$$

where $k_{jt} \equiv \frac{\frac{K'_{jt}}{A_{jt}(1+\beta_{jt})}}{\sum_{v=1}^J \frac{K'_{vt}}{A_{vt}(1+\beta_{vt})}} \in (0, 1)$. The last term in the above equation represents the spillover effects, which are preset in our set-up through the common net real interest rate. Clearly, due to $k_{jt} < 1$, the net effect on the domestic capital's user-cost of a change in the domestic tariff, or capital transaction cost or technology follows the corresponding direct effect. In other words, the effect on the user-cost of capital through the net real interest rate is not the dominant one.

Collecting terms from (6), (10)–(14), (16) and (17) gives us the dependence of capital taxes on transaction costs, output-augmenting technology, tariffs, seignorage shares, foreign transfers of seignorage, public debt policy, inflation, and pre-determined holdings of money and private and public bonds.^{39,40}

³⁹ Φ_{jt} (recall its definition in Appendix C) depends on the future net real interest rates. It also depends on future inflation, user-costs of capital, money holdings, future public good provision and future taxes, transaction costs and output-augmenting technologies. How do these depend on the period- t tariffs, output-augmenting technologies and other important determinants is ambiguous without further restrictions on preferences and various parameters. Investigating these effects is out of the scope of the current work, and therefore are not discussed further.

⁴⁰Of course, $r_{jt}, R_{jt}, \Phi_{jt}$ and λ_{jt} depend also on the capital tax. Note, however, after assuming that the second order conditions are satisfied, that E_{jt} is strictly decreasing with τ_{jt} . Hence, the effect of a policy or a parameter on the equilibrium capital tax has the sign of the net effect of the policy or parameter in question on E_{jt} . Therefore, collecting terms as stated in the text above is valid for the understanding of the determination of the equilibrium capital tax.

Table A1
Summary Statistics for European Union* (17 members; 1975-2005).

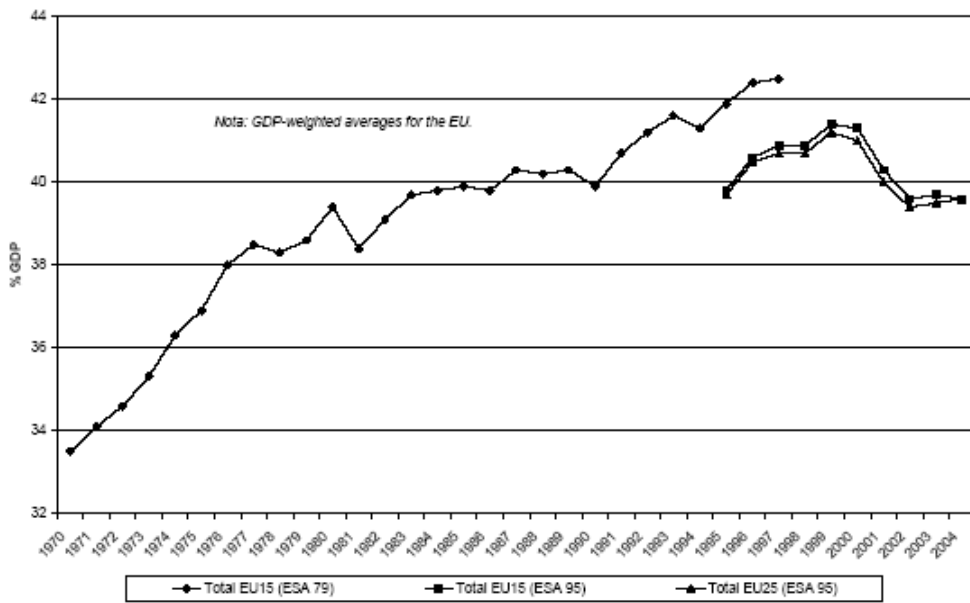
Variable	Description	Mean	Min	Max	Source
τ_{it}	Highest marginal tax rate, corporate rate	0.431	0.09	0.689	KPMG, Corporate Tax Rate Survey, Switzerland.
Agriculture, value added	Agriculture, value added (% of GDP)	0.039	0.011	0.431	World Development Indicators (Edition: September 2006).
GDP	GDP values**	4241.71	1104.2	8.175	World Development Indicators (Edition: September 2006).
Debt	Total debt, as a proportion of GDP	119.00	85.08	137.43	European Commission, 2006.
Inflation	The yearly percentage change in the consumer price index	0.087	-0.061	0.2721	OECD Economic Outlook.
openness	The sum of exports and imports divided by 1.000.000*GDP and lagged one year	0.032	-0.276	0.495	OECD Economic Outlook.
Market capitalization	Market capitalization of listed companies (% of GDP)	0.384	0.091	0.688	World Development Indicators (Edition: September 2006).
Population	Population, total**.	20,271	7,003	82,095	European Commission, 2006.
Unemployment	Unemployment, total (% of total labor force)	0.077	0.029	0.155	OECD Economic Outlook.
Wages	Workers' remittances and compensation of employees***.	34,567	10,250	85,069	World Development Indicators (Edition: September 2006).
Euro	Dummy = 1 if the country has adopted euro currency and 0 otherwise.				European Commission, 2006.
Eu	Dummy = 1 if the country is a member of the European Union and 0 otherwise.				European Commission, 2006.

*European Union of 17 members refers to the case before the expansion of EU in 2004 and includes Switzerland and Norway.

** The variable is multiplied by 10^3 when it is used in the regression analysis.

*** The variable is multiplied by 10^5 when it is used in the regression analysis.

Figure 1: Taxes as a % of GDP in EU



Note: Eurostat changed its classification in 1995. The source of the graph is European Commission (2006).

Table 1: Basic and Augmented specifications

Model Specification	Dependent Variable: Marginal tax rate, corporate rate (%)						
	(1)	(2)	(3)	(4) FE	(5) RE	(6) FE	(7) RE
constant	108.12* (2.39)	126.85* (2.49)	123.61* (2.22)	141.42* (2.41)	-5.68 (-1.03)	189.57* (2.06)	15.11 (1.32)
Lagged taxes	0.22 (0.61)	0.14 (0.35)	0.16 (0.41)	0.087 (0.20)	1.12* (2.80)	0.47 (2.37)*	0.49 (1.68)
Agriculture, value added	11.61* (2.26)	12.71* (2.33)	12.32* (2.11)	13.38* (2.18)	-0.57 (-0.92)	8.22* (2.78)	2.42 (1.54)
Gdp	-13.08* (-2.45)	-14.62* (-2.57)	-14.26* (-2.29)	-15.74* (-2.40)	0.52* (1.01)	-6.88** (-3.49)	-2.59* (-1.83)
Debt	0.74* (2.12)	0.71* (1.95)	0.68* (2.03)	0.65* (2.28)	0.56* (2.01)	0.66* (1.89)	0.54* (1.92)
Inflation	0.018 (0.60)	0.014 (0.41)	0.025 (0.76)	0.02 (0.59)	0.056* (2.39)	-0.019 (-0.62)	0.06 (2.49)
openness	0.008 (0.47)	0.014 (0.70)	0.009 (0.55)	0.014 (0.73)	52.3 (1.14)	0.02 (1.45)	0.02 (1.48)
Euro		0.59 (0.99)		0.52 (0.84)	-0.059 (-0.09)	1.05* (2.21)	-2.71 (-2.0)
Eu			1.42* (1.79)	1.49* (1.76)	0.11 (0.23)	1.42* (2.62)	0.92 (1.68)
Market capitalization						-0.02** (-3.89)	-0.02 (-0.82)
Population						-15.05 (-1.61)	1.12* (2.0)
unemployment						-0.02 (-0.21)	-0.07 (-1.60)
Wages						-0.19* (-2.23)	-0.16* (-1.87)
Country Dummies	No	No	No	Yes	Yes	Yes	Yes
Rsquared	0.58	0.52	0.56	0.49	0.68	0.75	0.70
Diagnostic tests							

Notes: T-statistics are given in parentheses. Standard errors are robust to heteroscedasticity, and are clustered by year to allow for spatial correlation in the errors. Also, *, **, and ***, respectively, indicate statistical significance at the 0.10, 0.05, and 0.01 levels.

2. Spatial and Economic Criteria (Neighboring taxes)

Spatial Criteria	European Union: 17 members [#]					European Union: 27 members ^{##}			
Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Economic Criteria	<i>None</i>	<i>Gdp=high</i>	<i>Gdp=low</i>	<i>Market Cap/tion</i>	<i>Wages</i>	<i>Exports</i>	<i>None</i>	<i>Gdp=high</i>	<i>Gdp=low</i>
Constant	8.11* (1.92)	12.12* (1.97)	-16.15 (-1.08)	-11.42 (-1.21)	15.17* (2.23)	10.38* (1.75)	5.11** (2.89)	9.17** (2.85)	19.01 (1.78)
Spatial Neighboring taxes	0.76* (1.95)	0.26* (2.83)	0.19* (1.93)	0.46** (2.88)	0.54* (2.27)	0.52* (2.01)	0.93* (2.14)	0.74* (2.03)	0.05 (0.78)
Economic Neighboring taxes		0.87* (2.02)	0.51* (1.82)	0.16 (1.27)	0.25 (1.21)	0.37 (1.45)		0.16* (1.87)	0.65* (1.94)
Lagged taxes	0.42* (1.71)	0.67* (1.78)	0.33* (1.83)	0.54* (1.95)	0.75* (1.99)	0.62* (1.93)	0.17* (1.92)	0.08* (1.96)	0.42* (1.85)
Agriculture, value added	1.92* (1.79)	2.86* (1.94)	3.68** (2.91)	1.89* (1.78)	0.87 (0.74)	1.92* (2.14)	1.79* (2.55)	1.56* (2.04)	2.61** (2.94)
Gdp	-2.56* (-1.99)	-2.11* (-1.88)	-1.54* (-2.03)	-1.75* (-1.93)	-1.38* (-2.09)	-1.59* (-2.17)	-2.86* (-1.91)	-2.27* (-1.96)	-1.87* (-2.11)
Debt	0.47* (1.56)	0.34* (1.88)	0.41** (3.16)	0.38* (1.95)	0.24* (1.74)	0.28* (1.94)	0.68* (2.37)	0.32* (2.07)	0.38* (2.01)
Inflation	0.03* (1.83)	0.11* (1.79)	0.04 (0.93)	0.01* (1.75)	0.01 (1.68)	0.09 (1.04)	0.09* (1.89)	0.05* (1.85)	0.07 (1.95)
Openness	0.01 (0.07)	0.04 (1.02)	0.08 (1.21)	0.09 (1.22)	0.12 (0.55)	0.07 (0.36)	0.28* (1.89)	0.21* (1.77)	0.14* (1.81)
Euro	-0.92* (-1.88)	-1.75* (-2.32)	-2.31* (-1.85)	-1.55* (-1.72)	-1.83* (-1.94)	-2.06* (-2.03)	-1.74* (-1.79)	-1.35** (-2.47)	-2.45* (-1.97)
Eu	0.44* (1.91)	0.53* (1.88)	0.71* (2.03)	0.58* (1.95)	0.64* (2.07)	0.71* (2.41)	0.96* (1.88)	0.84* (1.82)	0.79* (2.09)
Market capitalization	-0.06* (-2.27)	-0.03* (-2.15)	-0.11* (-2.41)	-0.17* (-1.95)	-0.56 (-0.95)	-0.89 (-0.88)	-0.12* (-2.19)	-0.09* (-2.11)	-0.04* (-2.02)
Population	1.01* (2.55)	1.04* (2.22)	0.31 (0.96)	0.45* (1.84)	0.37* (1.93)	0.18 (0.81)	0.58* (1.91)	0.67* (1.84)	0.11 (0.27)
Rsquared	0.61	0.68	0.65	0.67	0.68	0.70	0.68	0.77	0.67
F-test	323.74	547.89	678.54	756.91	611.55	589.88	359.15	225.74	198.43
Year Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes:

1. T-statistics are given in parentheses. Standard errors are robust to heteroscedasticity, and are clustered by year to allow for spatial correlation in the errors. Also, *, **, and ***, respectively, indicate statistical significance at the 0.10, 0.05, and 0.01 levels.

2. Neighboring explanatory variables are used as instruments for both spatial and economic weights.

3. European Union of 17 (#) members refers to the case before the expansion of EU in 2004 and includes Switzerland and Norway. European Union of 27 (##) members refers to the case after the expansion of EU in 2004 and covers the period 1993-2005.

Table 3: Robustness check

Spatial Criteria	European Union: 17 members [#]				European Union: 27 members ^{##}		
Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Economic Criteria	Gdp=high	Gdp=low	Market capitalization	Wages	Exports	Gdp=high	Gdp=low
Constant	53.88* (2.68)	45.17* (1.75)	59.85* (2.23)	24.12* (1.88)	18.65* (1.71)	22.15 (1.21)	11.87 (0.84)
Spatial	0.28* (2.11)	0.35* (1.82)	0.54* (2.41)	0.61* (2.04)	0.58* (1.92)	0.86* (2.19)	0.17 (0.67)
Neighboring taxes	0.71* (2.23)	0.87* (2.45)	0.37* (1.74)	0.23 (0.55)	0.58* (1.75)	0.37* (1.93)	0.55* (2.38)
Economic	0.61* (1.71)	0.83* (1.94)	0.71* (2.21)	0.49 (1.05)	0.42 (1.69)	0.89* (1.86)	0.59* (1.98)
Neighboring taxes	1.75* (2.48)	1.97* (2.01)	2.58* (1.76)	2.11 (1.45)	1.58* (1.93)	1.23* (2.01)	2.35** (2.77)
Lagged taxes	-1.46* (-2.41)	-1.21* (-1.72)	-1.79* (-2.02)	-1.44* (-2.41)	-1.17* (1.78)	-1.09* (-1.83)	-1.21* (-1.79)
Agriculture, value added	0.52* (1.83)	0.79* (2.34)	0.67* (1.84)	0.62* (1.93)	0.77* (2.06)	0.81* (2.17)	0.88* (2.41)
Debt	-0.05* (-1.83)	-0.29 (-0.56)	-0.35 (-0.43)	-0.71 (-0.12)	-0.58 (1.01)	-0.11* (-1.98)	-0.21 (-1.31)
Inflation*Euro	1.59* (2.16)	4.73 (0.72)	3.31 (1.21)	3.89 (0.87)	2.57 (0.96)	1.87** (2.89)	0.77 (0.51)
Openness*euro	0.11* (1.78)	0.14* (2.16)	0.09* (1.91)	0.75 (1.27)	0.71 (0.41)	0.19* (2.12)	0.09* (2.01)
Market capitalization	1.85* (2.63)	1.12* (1.71)	1.37* (1.72)	0.98 (1.12)	0.71 (1.03)	1.25* (2.81)	1.78* (1.85)
Eu	0.91 (1.08)	0.86 (1.09)	0.72 (0.84)	1.31 (1.22)	0.67 (0.52)	0.51 (0.74)	0.42 (1.08)
Population	-0.09 (-0.39)	-0.08 (-0.02)	-0.12 (-0.31)	-0.17 (-0.95)	-0.14 (-0.23)	-0.03 (-0.21)	-0.05 (-0.02)
Unemployment	-0.31 (-0.11)	-0.42 (-0.17)	-0.18 (-0.05)	-0.28 (-0.09)	-0.51 (-0.12)	-0.72 (-0.18)	-0.49 (-0.11)
Wages							
Rsquared	0.58	0.61	0.56	0.55	0.52	0.67	0.56
F-test	481.11	841.61	619.81	533.81	801.71	359.17	229.44
Year Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes:

1. T-statistics are given in parentheses. Standard errors are robust to heteroscedasticity, and are clustered by year to allow for spatial correlation in the errors. Also, *, **, and ***, respectively, indicate statistical significance at the 0.10, 0.05, and 0.01 levels.

2. Neighboring explanatory variables are used as instruments for both spatial and economic weights.

3. European Union of 17 (#) members refers to the case before the expansion of EU in 2004 and includes Switzerland and Norway. European Union of 27 (##) members refers to the case after the expansion of EU in 2004 and covers the period 1993-2005.

4. Temporal dependence

Estimation Method ^a	Dependent Variable: Marginal tax rate, corporate rate (%)					
	(1) FGLS	(2) PW- PCSE	(3) FGLS	(4) PW- PCSE	(5) FGLS	(6) PW- PCSE
Constant	9.23* (1.78)	7.43* (1.98)	2.42 (1.05)	8.47* (2.88)	6.15* (1.95)	4.31* (1.88)
Spatial Neighboring taxes	0.19* (1.87)	0.37* (1.88)	0.42* (2.02)	0.44* (1.78)	0.38* (1.76)	0.35* (1.75)
Economic Neighboring taxes	0.54** (2.59)	0.78* (1.89)	0.58* (2.01)	0.79* (1.78)	0.94* (1.75)	0.84* (1.72)
Lagged taxes			0.77** (2.64)	0.89* (1.73)	0.95* (2.02)	0.82** (2.89)
Agriculture, value added Gdp	0.58 (1.02)	2.11* (2.07)	0.54* (1.89)	2.31** (2.71)	1.06 (0.56)	0.86 (0.15)
Debt	-2.47* (-1.96)	-0.78** (-2.77)	-2.59* (-2.08)	-0.68* (-2.36)	-1.14* (-1.86)	-1.28* (-1.89)
Inflation	0.37* (1.81)	0.31* (1.94)	0.42* (1.89)	0.35* (1.77)	0.45* (2.01)	0.51* (2.11)
openness	0.45 (0.58)	0.02* (1.92)	0.37 (1.05)	0.01 (1.68)	0.05* (1.81)	0.07* (1.89)
Euro	0.09 (1.35)	0.15 (1.02)	0.06* (1.97)	0.07* (1.86)	0.09* (1.73)	0.09* (1.73)
Eu	-1.03* (-1.98)	-2.05* (-1.71)	-1.14 (-1.68)	-1.96* (-2.07)	-1.34** (-2.67)	-1.11* (-2.01)
Market capitalization	0.19* (1.99)	0.28* (1.85)	0.23* (1.76)	0.33* (2.19)	0.42* (1.88)	0.43* (1.93)
Population	-0.11 (-0.01)	-0.05 (-0.74)	-0.09 (-1.23)	-0.07 (-1.24)	-0.19 (-1.01)	-0.25 (-0.95)
Unemployment	0.64* (1.78)	0.29 (1.07)	0.53* (1.89)	0.41* (1.77)	0.51* (1.81)	0.45* (1.88)
Wages	-0.15 (-0.79)	-0.27 (-0.52)	-0.18 (-0.39)	-0.24 (-0.23)	-0.12 (-0.36)	-0.28 (-0.23)
rho	-0.12 (-1.54)	-0.14 (-1.03)	-0.09* (-1.94)	-0.08* (-2.01)	-0.05* (-1.83)	-0.06* (-1.89)
Rsquared		0.78		0.79		0.79
Year Effects	No	No	Yes	Yes	Yes	Yes

Notes: T-statistics are given in parentheses. Also, *, **, and ***, respectively, indicate statistical significance at the 0.10, 0.05, and 0.01 levels.

^aFGLS= feasible GLS estimation; PW-PCSE= Prais-Winsten estimation with panel-corrected standard errors.