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## Fiscal competition over taxes and public inputs - theory and evidence

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## WORKING PAPER SERIES

NO 1033 / MARCH 2009

# FISCAL COMPETITION OVER TAXES AND PUBLIC INPUTS

## THEORY AND EVIDENCE

by Sebastian Hauptmeier  
Ferdinand Mittermaier  
and Johannes Rincke



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### THEORY AND EVIDENCE<sup>1</sup>

by Sebastian Hauptmeier<sup>2</sup>,  
Ferdinand Mittermaier<sup>3</sup>, and Johannes Rincke<sup>4</sup>



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## Abstract

We set up a model to characterize the reaction functions of governments competing for mobile capital by simultaneously setting both the business tax rate as well as the level of provision of a productive public input. Using a rich data set of local jurisdictions, we then test the predictions of the model with respect to the nature of strategic interaction among governments. Our findings from efficient estimation of a system of spatially interrelated equations for both policy instruments support the notion that local governments use both the business tax rate and public inputs to compete for capital. In particular, we find that if neighbors cut their tax rates, governments try to restore competitiveness by lowering their own tax and increasing spending on public inputs. If neighbors provide more infra-structure, governments react by increasing their own spending on public inputs.

Keywords: Tax competition, public input competition, system estimation

JEL Classification: H72, H77, C72



# Non-technical Summary

It has long been recognized that governments may use various instruments to attract mobile factors. With regard to capital, two of these instruments have received special attention: Business taxes and public infrastructure investment, e.g. spending on the road network. While it seems natural to think of governments' choices regarding tax rates and public inputs to private production to be closely interrelated, the literature on fiscal competition has mostly treated them separately. This paper is an attempt to overcome this deficiency. We characterize general reaction functions of local governments from a model of tax and public input competition. Using data on a large sample of German municipalities, we estimate an empirical counterpart of the system of fiscal reaction functions, thereby providing evidence on fiscal competition in a model treating taxes and spending on infrastructure as jointly determined endogenous variables.

The theoretical literature has pointed to the role of taxes and infrastructure investments as joint determinants of private investment early on. Extending the analysis of Zodrow and Mieszkowski (1986), Keen and Marchand (1997) have shown that in the presence of a productivity-enhancing public good the composition of public spending tends to be systematically biased towards a relative overprovision of public inputs compared to public goods which are consumed directly by residents. Focusing on the strategic choice of policy instruments, Buettner (1999) has suggested a model where governments optimize over tax rates and shares of income that are spent on productive public goods. More recently, Hindriks et al. (2008) have presented a framework in which the level of public inputs is chosen in the first stage of a game while the tax rate is determined in the second. This dynamic setting implies an incentive for governments to underinvest in public inputs in order to alleviate second-stage tax competition. In contrast to the aforementioned contributions, the bulk of theoretical work on fiscal competition has treated the cases of pure tax competition and expenditure competition separately. While Mintz and Tulkens (1986), Wilson (1986), and Wildasin (1988) have discussed the issue of inefficiently low equilibrium tax rates and a corresponding underprovision of consumptive public goods, Taylor (1992) and Bucovetsky (2005) have dealt with the problem of overprovision of public infrastructure. The related empirical literature has been dominated by applications

testing for the strategic choice of business tax rates, mostly ignoring the issue of public inputs. Early contributions include Brueckner and Saavedra (2001), Buettner (2001), and Hayashi and Boadway (2001).

Building on much of the theoretical as well as empirical work mentioned above, we offer a comprehensive treatment of tax and public input competition, with a focus on the strategic behavior of governments in choosing both policy instruments. In our theoretical model, the governments of two symmetric jurisdictions compete for mobile capital by simultaneously setting both the business tax rate as well as the level of provision of a productive public input. We characterize the reaction functions for both policy instruments and show that governments react to tax cuts in the other jurisdiction by cutting their own tax rate and providing more public inputs. If the other jurisdiction improves its infrastructure, governments lower the business tax rate and increase the provision of public inputs. We then proceed with an empirical test of the nature of strategic behavior of governments with autonomy to set a business tax rate and to provide a productive public input. Using a rich data set of local jurisdictions in Germany, we estimate an empirical counterpart of the two-dimensional system of fiscal reaction functions. To the best of our knowledge, we provide the first empirical analysis of tax and public input competition that allows for taxes and spending on infrastructure to be jointly determined endogenous variables. The picture of local government behavior that emerges from our estimations is much more complex than suggested by previous empirical work on fiscal competition. Across various specifications, our findings point to simultaneous tax and public input competition for mobile capital. In particular, our results suggest that municipalities experiencing a boost in local infrastructure investment in neighboring communities will, on average, raise the level of public input provision, too. If neighbors choose to lower the tax burden on locally installed capital, municipalities not only adjust their own tax rates, but also increase their spending on infrastructure. All these empirical findings are in line with the predictions of our theoretical model.



# 1 Introduction

It is widely believed that national as well as local governments have powerful tools to affect the allocation of mobile capital, and that how these tools are used has significant consequences for the welfare of citizens. However, compared to the vast overall number of factors typically regarded as crucial for private investors when deciding where to invest, governments have mainly two sets of instruments at their disposal that directly affect investors' choices: the taxation of businesses and the provision of public inputs. When analyzing government behavior related to competition for capital, it thus seems natural to assume that governments make use of both available instruments, and that the choices affecting the taxation of firms and decisions on public input provision will typically be interdependent. Accordingly, a thorough analysis of how governments compete for mobile capital should be based on analytical tools treating the relevant business tax rates and infrastructure investments as jointly determined policy instruments.

The theoretical literature has pointed to the role of taxes and infrastructure investments as joint determinants of private investment early on. Extending the analysis of Zodrow and Mieszkowski (1986), Keen and Marchand (1997) have shown that in the presence of a productivity-enhancing public good the composition of public spending tends to be systematically biased towards a relative overprovision of public inputs compared to public goods which are consumed directly by residents. Focusing on the strategic choice of policy instruments, Buettner (1999) has suggested a model where governments optimize over tax rates and shares of income that are spent on productive public goods. More recently, Hindriks et al. (2008) have presented a framework in which the level of public inputs is chosen in the first stage of a game while the tax rate is determined in the second. This dynamic setting implies an incentive for governments to underinvest in public inputs in order to alleviate second-stage tax competition.

In contrast to the aforementioned contributions, the bulk of theoretical work on fiscal competition has treated the cases of pure tax competition and expenditure competition separately. While Mintz and Tulkens (1986), Wilson (1986), and Wildasin (1988) have discussed the issue of inefficiently low equilibrium tax rates and a corresponding underprovision of consumptive public goods, Taylor (1992) and Bucovetsky (2005) have dealt with

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Building on much of the theoretical as well as empirical work mentioned above, we offer a comprehensive treatment of tax and public input competition, with a focus on the strategic behavior of governments in choosing both policy instruments. In our theoretical model, the governments of two symmetric jurisdictions compete for mobile capital by simultaneously setting both the business tax rate as well as the level of provision of a productive public input. The public input makes private capital more productive and can thus be used by governments to attract investment. On the other hand, providing public inputs is costly. We characterize the reaction functions for both policy instruments and show that governments react to tax cuts in the other jurisdiction by cutting their own tax rate and providing more public inputs. If the other jurisdiction improves its infrastructure, governments lower the business tax rate and increase the provision of public inputs. We then proceed with an empirical test of the nature of strategic behavior of governments with autonomy to set a business tax rate and to provide a productive public input. Using a rich data set of local jurisdictions in Germany, we estimate an empirical counterpart of the two-dimensional system of fiscal reaction functions. To the best of our knowledge, we provide the first empirical analysis of tax and public input competition that allows for taxes and spending on infrastructure to be jointly determined endogenous variables. Building on recent work of Kelejian and Prucha (2004), we run a four-step systems estimation approach for spatially interrelated equations. Our approach is very general. First of all, it allows for both policy instruments to depend on tax rates and public inputs in neighboring jurisdictions. Secondly, we treat the business tax rate as a function of a government's own level of public input provision, and vice versa. Thirdly, it accounts for potential cross-sectional correlation in unobservables and potential cross-equation correlation of residuals.

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<sup>1</sup>One of the few empirical studies acknowledging the joint impact of taxes and public infrastructure on the allocation of private capital is Bénassy-Quéré et al. (2007). They investigate FDI flows from the U.S. to several European countries and find that both the corporate tax rate and the stock of public capital are significant in explaining inward FDI. In contrast to their study, we take the responsiveness of investment to inter-jurisdictional differences in tax rates and public infrastructure as given and explore whether governments make use of taxation and public inputs as strategic instruments to attract private capital. A further study providing some related evidence on OECD countries is Gomes and Pouget (2008).

The picture of local government behavior that emerges from our estimations is much more complex than suggested by previous empirical work on fiscal competition. Across various specifications, our findings suggest that governments set both the business tax rate and the level of public input provision strategically, i.e. they set both instruments taking into account the respective choices of competing governments. In particular, we find that local governments tend to adjust their business tax rate towards levels chosen in neighboring jurisdictions. Moreover, if neighbors increase their spending on the local infrastructure, governments react by strongly increasing their own spending, too. Finally, our results suggest that a government's level of spending on public inputs is also affected by the tax rates of neighboring jurisdictions, with the sign of the effect as predicted by the theoretical model. Treating taxes and public inputs as alternative means to attract capital thus reveals that local governments react to competition by other jurisdictions in a rather flexible way: municipalities experiencing a boost in local infrastructure investment in neighboring communities will, on average, raise the level of public input provision, too. If neighbors choose to lower the tax burden on locally installed capital, municipalities will adjust both the tax rate and the spending on infrastructure to restore competitiveness. All these empirical findings are in line with the predictions of our theoretical model.

The paper proceeds as follows. In Section 2 we introduce our theoretical model of tax and public input competition. Section 3 describes our estimation approach and presents evidence based on data on local jurisdictions in Germany. Conclusions are drawn in Section 4.

## 2 The model

Our theoretical analysis of tax and public input competition builds on the literature on strategic tax competition in the tradition of contributions such as Wilson (1991), Wildasin (1991) and Brueckner and Saavedra (2001). In these models, governments compete for capital which is in fixed supply, and countries are large enough to have an influence on each other's optimal behavior. We extend this model of pure tax competition by allowing for public inputs as a second strategic policy instrument. Our aim is to characterize the model's reaction functions, describing how governments react with both instruments to the respective choices of a competing jurisdiction. Since we want to account for strategic

interaction across instruments, we let governments simultaneously set taxes and spending on the public input. The governments in our model thus compete by choosing a mix of instruments capable of attracting mobile capital. The simultaneity in the choice of fiscal policies, which rules out commitment effects emerging in a setting with sequential moves, is what differentiates our model most from the framework used by Hindriks et al. (2008).

We consider a federation of two symmetric jurisdictions, labeled  $i = 1, 2$ . In each jurisdiction, production of a homogeneous consumption good takes place, using perfectly mobile capital  $k_i$  and a publicly provided input,  $g_i$ . The public input is of the factor-augmenting type and raises the marginal productivity of the primary input factor. To keep the model tractable, we use a simple quadratic production function of the form

$$F_i(k_i, g_i) = (a + g_i)k_i - b \frac{k_i^2}{2}, \quad (1)$$

where  $a$  and  $b$  are parameters. Governments levy per unit taxes  $t_i$  on capital employed in their jurisdiction. With capital perfectly mobile across regions, the arbitrage condition requires its net return to be equalized such that

$$F'_i(k_i, g_i) - t_i = F'_j(k_j, g_j) - t_j, \quad (2)$$

where  $F'_i$  denotes the marginal product of capital. With the world capital stock denoted as  $k$ , we can solve (2) for the capital employed in  $i$ ,

$$k_i = \frac{kb + g_i - g_j - t_i + t_j}{2b}. \quad (3)$$

Equation (3) shows how a government's own choice regarding  $t$  and  $g$  affects its tax base, and that making use of the instruments involves fiscal externalities. Note that due to the symmetric setting and the specification of the production function, we have

$$\frac{\partial k_i}{\partial g_i} = -\frac{\partial k_i}{\partial t_i} = -\frac{\partial k_i}{\partial g_j} = \frac{\partial k_i}{\partial t_j} = \frac{1}{2b}. \quad (4)$$

The governments are assumed to maximize welfare in their own jurisdiction. Assuming absentee ownership of capital,<sup>2</sup> we define the objective function of the government in  $i$  to be

$$U_i = F_i(k_i, g_i) - F'_i(k_i, g_i)k_i + t_i k_i - \frac{(k_i g_i)^2}{2}, \quad (5)$$

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<sup>2</sup>This simplifies the algebra, but all our main results hold if we allow for domestic ownership of capital.

where the first term captures total output, the second capital income of foreign owners, the third local tax revenue, and the fourth the cost of public input provision.

While the first three terms are straightforward, the expression capturing the cost of providing the productive input requires some discussion. First of all, including the cost of public input provision in the welfare function instead of imposing a budget constraint implies (realistically) that governments do not rely exclusively on capital taxes as the source of funding public inputs. Secondly, the specification avoids the need for a further policy instrument. Otherwise, with two instruments and the requirement to balance the government's budget, only one policy instrument could be set strategically.<sup>3</sup> The convex cost of supplying the public input captures a congestion externality in the use of the public input. Accounting for such an externality is motivated by two facts: first of all, the presence of congestion externalities seems to be a natural assumption with regard to common public inputs like road networks, telecommunication infrastructure or land for business parks.<sup>4</sup> Secondly, the existence of a pure-strategy Nash equilibrium in a simultaneous-move game with taxes and public inputs is only guaranteed in general if the latter is crowded to some degree (Petchey and Shapiro, 2008). The intuition for our specification of the congestion externality is that, for any given level of  $g$ , the welfare costs of providing it are higher the more it is used, i.e. the 'relative' costs of providing public inputs are convex. Stated differently, we assume that governments trying to ensure an adequate provision of  $g$  for any unit of  $k$  will see the costs of  $g$  rising with  $k$ . This is a standard way of modelling crowding externalities in the context of local public inputs (Matsumoto, 2000).<sup>5</sup> In anticipation of our empirical example involving jurisdictions providing a local road network, one might think of an increase in the number of vehicles to lead to a more than proportionate increase in the need for roads due to nonlinearities in congestion effects. Alternatively, one could argue that the maintenance costs of public infrastructure increase as it is being used more

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<sup>3</sup>As first discussed by Wildasin (1991), equilibria in fiscal competition games with two instruments related via a budget constraint crucially depend on which instrument is set strategically. See Bayindir-Upmann (1998) for an exploration with taxes and public inputs as policy instruments.

<sup>4</sup>Bergstrom and Goodman (1973) provide evidence suggesting that most local public goods are congestible. Craig (1987) finds substantial congestion effects using the example of police services, and Fernald (1999) shows that after 1973, with the U.S. Interstate Highway system being well-established, an increase in total miles driven reduced road services to individual producers significantly.

<sup>5</sup>An alternative would be to include the congestion externality in the production function (see Buettner, 1999). While this does not change the intuition for the crowding effect, it makes the algebra significantly more involved.



heavily. With respect to the specific functional form of the cost term, we follow Hindriks et al. (2008) by using a simple quadratic form. This constitutes a straightforward way to introduce cost convexity while keeping the model tractable.

Using (3) and (5), we derive the welfare level as a function of  $k_i$  as

$$U_i(k_i) = \frac{\delta_i}{8b^2} [b^2k + g_i^2(g_j - g_i + t_i - t_j) + b(g_i - g_i^2k - g_j + 3t_i + t_j)], \quad (6)$$

where  $\delta_i \equiv kb + g_i - g_j - t_i + t_j$ . Our main interest lies in the slopes of the tax and public input reaction functions,  $t_i = f_t(t_j, g_j)$  and  $g_i = f_g(t_j, g_j)$ , around the equilibrium. In most of the literature, policy instruments are referred to as ‘strategic substitutes’ if the derivative  $\partial^2 U_i / (\partial x_i \partial x_j)$  is negative, and as ‘strategic complements’ if it is positive, where  $x$  denotes an instrument at players’ disposal. With just one instrument, this translates one to one into negatively and positively sloped reaction functions, respectively. This is, of course, no longer true in our case as a government will generally find it optimal to respond to a marginal policy change by its competitor using both instruments. Taking account of this, to obtain the slopes of the tax and public input reaction functions, we proceed by totally differentiating the governments’ first order conditions with respect to  $t_i$  and  $g_i$ . In general form, the resulting system of equations reads

$$\begin{pmatrix} \frac{\partial^2 U_i}{\partial t_i \partial t_i} & \frac{\partial^2 U_i}{\partial t_i \partial g_i} \\ \frac{\partial^2 U_i}{\partial g_i \partial t_i} & \frac{\partial^2 U_i}{\partial g_i \partial g_i} \end{pmatrix} \begin{pmatrix} dt_i \\ dg_i \end{pmatrix} = - \begin{pmatrix} \frac{\partial^2 U_i}{\partial t_i \partial t_j} & \frac{\partial^2 U_i}{\partial t_i \partial g_j} \\ \frac{\partial^2 U_i}{\partial g_i \partial t_j} & \frac{\partial^2 U_i}{\partial g_i \partial g_j} \end{pmatrix} \begin{pmatrix} dt_j \\ dg_j \end{pmatrix}. \quad (7)$$

Since we assume jurisdictions to be identical, we follow the common practice to focus on the symmetric equilibrium characterized by  $t_i = t_j = t$  and  $g_i = g_j = g$ . Using the specific values of all the derivatives (note that we have relegated most formal derivations to the appendix), it is straightforward to derive from (7) the four effects of interest as

$$\frac{dg_i}{dg_j} = -\frac{dg_i}{dt_j} = \frac{1}{|H|} \frac{gk - 1}{4b^2} \quad (8)$$

and

$$\frac{dt_i}{dt_j} = -\frac{dt_i}{dg_j} = \frac{1}{|H|} \frac{k(bk + g(4 - 3gk))}{16b^2}, \quad (9)$$



where  $|H|$  denotes the determinant of the Hessian (it is shown in the appendix that  $|H|$  is positive). Note that the symmetries in  $dt_i/dt_j$  and  $dt_i/dg_j$  as well as  $dg_i/dg_j$  and  $dg_i/dt_j$  are driven by the fact that, as shown in (3), the absolute values of the marginal changes in the tax base are equal across instruments.

To sign the slopes of the reaction functions, we make use of the values for  $g$  and  $t$  in the symmetric Nash equilibrium, which turn out to be  $g^* = 2/k$  and  $t^* = (bk^2 + 4)/(2k)$  (see the appendix for derivations and discussion of stability).<sup>6</sup> If we evaluate (8) at the symmetric Nash equilibrium, we find unambiguous signs for the reactions in public inputs,

$$\frac{dg_i}{dg_j} = \frac{4}{3bk^2} > 0; \quad \frac{dg_i}{dt_j} = -\frac{4}{3bk^2} < 0. \quad (10)$$

The expressions in (10) show that if the opponent deviates from the symmetric equilibrium by increasing its supply of public inputs, a region will find it optimal to respond by supplying more  $g$ , too. Moreover, a region will also react by providing more of the costly input if the opponent competes for capital by cutting its tax rate.

Evaluating (9) in equilibrium, we see that the signs of the reactions in taxes depend on  $b$ , the parameter measuring the curvature of the production function:

$$\frac{dt_i}{dt_j} = \frac{bk^2 - 4}{3bk^2}; \quad \frac{dt_i}{dg_j} = -\frac{bk^2 - 4}{3bk^2}. \quad (11)$$

Hence, the finding of Brueckner and Saavedra (2001) that the slope of the reaction function in a model of pure tax competition cannot be signed unambiguously carries over to our setting. As long as we are willing to assume that  $b$  is larger than  $4/k^2$ , however, we find

$$\frac{dt_i}{dt_j} > 0; \quad \frac{dt_i}{dg_j} < 0. \quad (12)$$

Under the given restriction on  $b$ , the optimal reaction to a decrease in the opponent's tax rate is to decrease taxes and to increase public input provision. Similarly, if the opponent provides more public inputs, it is optimal to increase provision, too, and to cut the tax rate. Inspection of (10) and (11) reveals that the smaller is  $b$ , the stronger will be the reaction in public inputs and the smaller will be the reaction in taxes. This is intuitive, as the following example demonstrates: imagine region  $j$  becomes a tougher competitor for mobile capital

<sup>6</sup>Note that with absentee ownership, capital has a participation constraint, namely that its net of tax return has to be positive,  $F'(k_i, g_i) - t_i > 0$ . This condition reduces to  $a > bk$ , a mere parameter restriction.

by raising  $g_j$ . The government in  $i$  can respond to this with its two instruments,  $t_i$  and  $g_i$ , and will typically use both. The reason for the crucial role of  $b$  is that it determines the curvature of the production function, thereby driving the residual income the country earns (after having paid the mobile factor its marginal product). This residual income is, besides tax revenues, the reason why a country is interested in attracting capital in the first place. If  $b$  is very small, the production function is almost linear, rendering the residual income small and the motive to tax local capital comparatively more important. For  $i$ 's government it will then be optimal to respond to the increase in  $g_j$  by a relatively strong increase in  $g_i$ , thereby defending its tax base, and by an increase in its tax rate  $t_i$ . With a larger  $b$ , the residual income becomes more significant, strengthening the incentive to attract capital for its direct contribution to the region's welfare. If  $b$  is sufficiently large, the optimal response to an increase in  $g_j$  will therefore be to lower  $t_i$  and still increase the costly  $g_i$ .

Formally, the rationale for requiring  $b > 4/k^2$  can be seen from the components of a region's welfare, which after substitution of the residual income is

$$U_i = \frac{b}{2}k_i^2 + t_i k_i - \frac{(g_i k_i)^2}{2}. \quad (13)$$

Evaluating this expression at the symmetric Nash equilibrium shows that the condition  $b > 4/k^2$  is equivalent to the requirement that the residual income is larger than the cost of providing  $g$ . If this condition is not met, the welfare effect of attracting additional units of capital is negative once we net out the contribution of tax revenue. This makes the motive to raise tax revenue so strong that governments will react to increased competition by increasing their tax rate. Hence, imposing the condition  $b > 4/k^2$  essentially means to restrict attention to situations where fiscal policies are driven by a motive to attract investment as an income-generating factor and, at the same time, to raise tax revenue. Effectively, the condition ensures that governments react to policy changes in the competing jurisdiction by adjusting both fiscal policy instruments such that the adjustment in each instrument contributes to offsetting the resulting change in a region's relative attractiveness for private capital.

To get an intuition for the role of the congestion externality in shaping the strategic behavior of governments, consider the reason for the sign of  $dg_i/dg_j$  to be positive: with the

congestion externality in place, attracting additional units of capital drives up the cost for the public input. For governments, this affects the optimal fiscal policy mix by making the attraction of capital less and using the tax instrument to generate revenue more attractive. Hence, the congestion externality alleviates tax competition. With higher taxes, the tax base effect becomes more important, inducing governments to respond with an increase (decrease) in public input provision to a corresponding increase (decrease) abroad.

In the following, we suggest an approach to estimate empirical counterparts of the tax and public input reaction functions of local jurisdictions. Since the congestion externality in the use of the public input is a distinctive feature of our model, we use an example where such externalities arise quite naturally: the provision and maintenance of a local road network.

## 3 Empirical Analysis

### 3.1 Estimation Approach

To accommodate strategic government behavior as implied by our model, our estimation approach must be flexible enough to allow for tax rates and public inputs to be determined simultaneously. Moreover, the design of the empirical model needs to account for the interdependence of all jurisdictions' choices regarding taxes and inputs, i.e. each jurisdiction's tax rate as well as the level of inputs provided to attract mobile capital should be allowed to depend on both taxes and inputs of all other jurisdictions.

Our structural empirical model builds on  $t_i = f_t(t_j, g_j)$  and  $g_i = f_g(t_j, g_j)$  as the general form reaction functions of the tax and public input competition model. To facilitate estimation, we make use of linearized versions of these functions and define the following system of equations,

$$\tau_i = \theta_\tau s_i + \lambda_\tau \tau_{-i} + \varphi_\tau s_{-i} + \beta_\tau X_{\tau i} + u_i \quad (14)$$

$$s_i = \theta_s \tau_i + \lambda_s \tau_{-i} + \varphi_s s_{-i} + \beta_s X_{s i} + v_i, \quad (15)$$

where  $\tau$  denotes the tax rate and  $s$  a jurisdiction's spending on the public input,  $\tau_{-i} = \sum_j w_{ij} \tau_j$  and  $s_{-i} = \sum_j w_{ij} s_j$  indicate the average tax rate and average inputs of other

jurisdictions, weighted by the predetermined weights  $w_{i1}, \dots, w_{iN}$ , and  $X_{\tau i}$  and  $X_{si}$  denote vectors of control variables (including a constant) in the tax and input equation, respectively. The variables entering both  $X_{\tau i}$  and  $X_{si}$  are subsets of a set of exogenous variables,  $X_i = (x_{1i}, \dots, x_{Ki})$ .

Note that in specifying our system of equations, we include  $s_i$  among the right-hand side variables of the tax equation and  $\tau_i$  as an explanatory variable in the input equation. In doing so, we deviate from the usual approach to use counterparts of reduced-form reaction functions when estimating models of fiscal competition with more than one choice variable (see Devereux et al., 2008). The reason for allowing a government's own policy instruments to appear as explanatory variables is that we want the empirical model to allow for the fact that governments are not always free to adjust both instruments to optimal levels. For instance, governments might face political costs when frequently changing the business tax rate, and prefer to keep the tax rate constant if the difference between the optimal rate and the rate actually implemented is sufficiently small. Taking into account the effect on the government's budget, the optimal choice of public inputs should then be modeled as being conditional on a given business tax rate. A similar argument can be made with respect to public inputs, where investments often require considerable planning effort. As a result, it may take some time until a government can adjust its stock of public capital to the desired level. Again, this may affect the government's budget and, thereby, the tax rate.

Apart from modeling tax rates and inputs to be interrelated both within and across jurisdictions, we also allow for cross-sectional dependence in the disturbances  $u$  and  $v$ ,

$$u_i = \rho_u u_{-i} + \epsilon_i \quad \text{and} \quad v_i = \rho_v v_{-i} + \varepsilon_i, \quad (16)$$

where  $u_{-i} = \sum_j w_{ij} u_j$  and  $v_{-i} = \sum_j w_{ij} v_j$ . The innovation vectors  $\epsilon$  and  $\varepsilon$  are assumed to be identically and independently distributed with zero mean. Hence, we require that the innovations are free of spatial correlation. Note, however, that we allow for contemporaneous cross-equation correlation among innovations of the same cross-sectional unit.

Following most of the literature on tax competition among local jurisdictions, we choose a spatial metric which accounts for the physical distance between jurisdictions. Moreover, we also want the weights to reflect differences in the jurisdictions' size. We therefore use

the metric

$$w_{ij} = \frac{n_{ij} \text{pop}_j}{\sum_{k \neq i} n_{ik} \text{pop}_k},$$

where  $n_{ij}$  is an indicator for neighbors of  $i$  (with  $n_{ii} = 0$ ) and  $\text{pop}_j$  is  $j$ 's population. To determine which jurisdictions are 'neighbors' of a given community, we either use a maximum great circle distance between the centroids of jurisdictions, or we apply an  $m$ th-nearest-neighbors criterion, defining as neighbors the  $m$  nearest jurisdictions in terms of physical distance.

While our specification of the empirical reaction functions is more general than the commonly employed reduced-form version, it also makes the estimation of the parameters of interest more involved. In fact, allowing the choice variables to appear as explanatory variables means that we have to deal with a total of four endogenous explanatory variables:  $s_i$ ,  $\tau_{-i}$ , and  $s_{-i}$  in the tax equation, and  $\tau_i$ ,  $\tau_{-i}$ , and  $s_{-i}$  in the public input equation. To account for all endogeneity problems and to achieve efficient estimation, we use the spatial system estimator proposed by Kelejian and Prucha (2004). In the following, we briefly outline the four step estimation procedure.

As the initial step, we run a two-stage least squares (2SLS) procedure separately on the tax and the input equation, treating  $\tau_i$ ,  $s_i$ ,  $\tau_{-i}$  and  $s_{-i}$  as endogenous regressors. We use the same set of instruments in both estimations, containing  $x_{1i}, \dots, x_{Ki}$  as well as the corresponding first and second order spatial lags. In matrix notation, they can be written as  $WX_1, \dots, WX_K, WWX_1, \dots, WWX_K$ , where  $W$  denotes the  $N$ -dimensional square matrix of weights. Using the residuals of the first stage, in the second step of the procedure the spatial auto-regressive parameters  $\rho_u$  and  $\rho_v$  are estimated by the generalized moments method originally suggested by Kelejian and Prucha (1999). The estimates of the spatial auto-regressive parameters are then used in the third step to perform a Cochrane-Orcutt-type transformation of the structural equations to remove the spatial error correlation and to re-run 2SLS on the transformed system. While the third-step estimation takes into account potential spatial correlation, it does not take into account the cross equation correlation in the innovation vectors. To utilize the full system information, in the fourth step we apply a systems instrumental variable estimator, which is efficient relative to the first and third stage single-equations estimators.

For several reasons, the systems estimation approach outlined above seems to be the ideal choice for estimating our tax and public input competition model. First of all, the procedure takes account of the fact that both taxes and public inputs are determined simultaneously. Secondly, it allows for contemporaneous interaction between jurisdictions in a very general way. In addition, it is easy to implement even in large samples, a distinctive advantage over maximum likelihood procedures.

The evidence reported in this study is derived from cross-sectional estimations. There are several reasons why panel estimations do not constitute a feasible option. First of all, the systems estimator of Kelejian and Prucha (2004) is designed for cross-sectional data. A straightforward way to account for unobserved heterogeneity would be to apply the estimation routine to panel data and to include a series of jurisdiction-specific constants as ordinary regressors. With more than 1,000 cross-sectional units, however, computational limitations hindered us to estimate panels with a reasonable time dimension. Based on short panels of up to four years, we were unable to identify the coefficients of interests with reasonable precision. The likely reason is that many variables, including the tax rate, show only limited variation over time. As in many related applications, it is thus difficult to achieve identification in a fixed effects framework with a small number of cross-sections.

## 3.2 Data

The data used to estimate our empirical model of tax and public input competition come from a sample of 1100 German municipalities in the state of Baden-Wuerttemberg, covering the period 1998-2004. Note that we exclude independent cities from the sample (10 cross-sectional units), which face different incentives within the municipal system of fiscal equalization. As we will see, the treatment within this redistributive grant system exerts a strong impact on local tax and spending decisions. In the following, we briefly comment on the data which are summarized in Table 1.

As already pointed out, German municipalities have taxing autonomy with respect to the business tax (Gewerbesteuer), essentially a tax on local business earnings. In the time period under consideration, the statutory tax rate in the state of Baden-Wuerttemberg averaged 0.167 and varied between 0.145 and 0.21. Besides revenues from the local business



Table 1: Descriptive statistics

Variable	Mean	Std. Dev.	Min	Max
Statutory tax rate, $\tau$	0.167	0.006	0.145	0.210
Spending for local roads per capita, $s$	130	92.8	0.815	1739
Marginal contribution rate	0.132	0.011	0.088	0.145
Unconditional transfers per capita	300	50.3	96.5	447
Fiscal capacity	0.714	0.272	0.276	6.35
Specific grants for local roads per capita	27.3	53.7	-76.5	1730
Other specific grants per capita	57.4	33.0	-3.92	282
Debt service per capita	10.6	35.2	-858	280
Population (1,000s)	7.81	10.7	0.101	112
Population density <sup>a</sup>	0.300	0.302	0.017	2.50
Unemployment	0.062	0.013	0.025	0.127
% population < 16 years	0.181	0.022	0.101	0.300
% population > 65 years	0.155	0.027	0.071	0.347
% church members	0.891	0.053	0.706	1.04

<sup>a</sup> (total population)/1000 per square kilometer; Nob=7700 (1100 municipalities from 1998 to 2004, independent cities excluded); Fiscal variables in Euros (prices of 2000). Source: Statistical Office of Baden-Wuerttemberg and own calculations.

tax, grants and federal tax revenue sharing play an important role in municipal financing. In our context of tax and public input competition, fiscal equalization grants deserve special attention, as redistributive grant systems affect the incentive of local governments with respect to tax and expenditure policies. The theoretical literature on the internalizing effects of fiscal capacity based equalization suggests that the implementation of redistributive grant systems tends to weaken tax and public input competition (e.g., see Koethenbueger, 2002 and Bucovetsky and Smart, 2006). Recent empirical evidence for Germany (Buettner, 2006; Egger et al., 2007) supports the view that tax rates tend to rise when the degree of equalization increases. Following Buettner (2006), we therefore include two control variables in our regressions to account for substitution and income effects of equalization grants. The marginal contribution rate describes to which extent an increase in the tax base reduces the equalization transfers received. For the period between 1998 and 2004 the average rate was 13.2% with a maximum value of 14.5% and a minimum of 8.8%. Relating the marginal contribution rate to the tax rate reveals an average equalization rate of around 80%. As a means to control for pure income effects we include unconditional transfers capturing the amount of transfers a municipality would receive if its tax base were actually zero. This includes equalization transfers and the municipal share of statewide income and value added taxes.

Furthermore, since differences in taxing capacity may affect local tax and expenditure policies, we account for a municipality's relative fiscal capacity. This variable is calculated by relating a municipality's fiscal capacity (comprising the local business tax base as well as other revenue sources, in particular the share of statewide income and value added taxes) to its fiscal need, calculated by multiplying a predefined per capita spending need with the municipality's population size. The relative fiscal capacity shows values between 28% and 635% with an average value of 71.4%.<sup>7</sup>

In our analysis, public input provision is defined as spending on the municipal road network. Between 1998 and 2004, municipalities have spent, on average, 130 Euros per capita (in prices of 2000) on the construction and maintenance of local roads. A standard deviation of 93 Euros per capita indicates substantial variation in this expenditure category.<sup>8</sup> As municipalities receive grants in order to fulfill their self-administrated spending responsibilities, we explicitly control for specific transfers in the spending category 'local roads'. This includes grants within the so called 'traffic and transport burden sharing' (Verkehrslastenausgleich), which depend on the length of the road network and the size of the municipal area. In addition, we include other specific grants independent of the tax base in order to control for the corresponding income effects. Other conditioning variables capturing local characteristics include debt service, population size and population density as well as the population share of the young (less than 16 years) and the elderly (above 65 years). Furthermore, we also include the unemployment rate as a proxy for the general demand for spending on social services. Finally, drawing on Buettner (2001), we include the share of the population that is affiliated with one of the three major Christian churches (Catholic, Protestant State, and Protestant Free Church) as well as two variables that interact this proportion with the rate of unemployment and the share of elderly people, respectively.<sup>9</sup> The inclusion of these variables is warranted as the religious orientation of the population

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<sup>7</sup>See Buettner (2006) for further details on the municipal system of fiscal equalization in the state of Baden-Wuerttemberg.

<sup>8</sup>Note that our public input variable is limited to spending on roads within a respective municipality. Streets which are not purely regional, e.g. interconnecting streets or highways, are usually financed by the state or/and the federal level. This is important as a potential interregional complementarity of spending on street infrastructure might interfere with our interpretation of spending competition among municipalities.

<sup>9</sup>Data on religious affiliation is available only for 1987. The slight imprecision in the count of church members relative to overall population (10 municipalities with a reported share of church members higher than one) is known from other studies using the same data. Excluding municipalities with implausible figures does nothing to our estimation results.

may indicate preferences regarding the provision of local public goods and, in particular, social services and welfare. The interactions account for the possibility that, depending on the strength of religious orientation, an increase in the number of potential welfare recipients may have different effects on the socially preferred level of social services.

The fact that both the tax rate and public inputs appear as explanatory variables in our system of equations requires to use some of the exogenous characteristics as instruments for these variables. Technically, this is achieved by imposing exclusion restrictions with respect to a subset of the exogenous variables on both equations. An exclusion restriction for the tax equation is suggested by the system of specific grants. As specific grants for the construction and maintenance of local roads amount, on average, to only 1.2% of overall expenditures, the business tax rate should be independent of the level of these grants. To the contrary, we expect grants for local roads to significantly affect actual spending on the local road network. Consequently, we include specific grants in the public input equation, but exclude it from the tax equation. Note that other specific grants amount to 57.4 Euros per capita, twice as much as specific grants for local roads. We therefore include other specific grants in both equations to account for potential income effects.

Regarding the exclusion restrictions for the public input equation, note first that local roads are not only used as public inputs by firms, but are also consumed by private households. A change in infrastructure spending will therefore have direct as well as indirect effects on the utility of residents. In contrast, a change in the business tax rate will affect households only indirectly. This suggests to exclude the variables describing the religious orientation of the local population and related preferences regarding spending on social services from the input equation. We thus assume that a stronger preference for spending on social services and welfare may affect the preferred level of local taxation, but that the level of municipal spending on physical infrastructure is independent of residents' religious orientation.

Of course, the quality of the instruments obtained from imposing our exclusion restrictions is also an empirical question. In particular, to identify public inputs in the tax equation, we need the specific grants for local roads to be sufficiently strongly partially correlated with spending on local roads. Furthermore, the identification of the local business tax rate in the input equation rests on the partial correlations between the tax rate and the proportion

of church members as well as the related interaction terms. We will discuss the quality of the instruments when turning to the estimation outcomes.

### 3.3 Results

Table 2 and 3 present detailed estimation results for a first set of system estimations on tax and public input competition. The spatial metric is  $W_{\text{pop adj}}^{15\text{km}}$ , defining as neighbors of a given community all municipalities with a physical distance of up to 15 km. As discussed above, the metric also gives higher weight to larger municipalities in terms of population size. As mentioned above, we report results from cross-sectional estimations. To check for the robustness across years, the tables depict regressions for different years.

After excluding the 10 independent cities from the sample, we are left with 1100 cross-sectional observations. Note that the sample restriction is applied after taking spatial lags. Hence, while all municipalities are included in the computation of  $\tau_{-i}$  and  $s_{-i}$ , the IV estimations at the first, third and fourth step of the system estimation approach are based on the restricted sample.

Table 2 reports two columns for each year, where the left one shows estimated coefficients and corresponding standard errors for the tax equation and the right one depicts the results for the public input equation. The coefficients of our variables of interest are shown in the first rows. First of all, we note that the coefficient of neighbors' taxes is positive and highly significant in the tax equation in all reported cross-sections, ranging from 0.20 to 0.31. These results suggest that the municipalities in our sample react to tax policies of their neighbors by adjusting their own business tax rate towards the level chosen in nearby jurisdictions.<sup>10</sup> Note that this finding is well in line with the evidence presented in Buetner (2001). However, our results also reveal that there are several other effects at work, suggesting that the behavior of local governments is much more complex than described in the earlier empirical tax competition literature. In particular, we find a positive and statistically significant effect of neighbors' spending on infrastructure on a community's own

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<sup>10</sup>In the following, we sometimes interpret the estimates of the strategic effects in terms of reactions of governments to changes in other municipalities' policy instruments. Such interpretations always refer to the partial effects in our static empirical model, and not to any sort of dynamic adjustment.

Table 2: Tax and public input competition, system estimation using  $W_{pop\ adj}^{15km}$ 

Cross section	1998		2000		2002		2004	
Dependent variable	$\tau$	$s$	$\tau$	$s$	$\tau$	$s$	$\tau$	$s$
Neighbors' tax rate	0.196*** (0.049)	-731** (350)	0.207*** (0.049)	-1055** (427)	0.278*** (0.055)	68.4 (559)	0.314*** (0.058)	60.0 (480)
Neighbors' public input	-0.000 (0.000)	0.178* (0.095)	-0.000 (0.000)	0.507*** (0.096)	0.000 (0.000)	0.237** (0.124)	0.000 (0.000)	0.148 (0.108)
Own tax rate	-	3190*** (801)	-	2396*** (924)	-	-2176** (1057)	-	-171 (772)
Own public input	0.00002*** (4D-06)	-	0.00001*** (4D-06)	-	0.000 (0.000)	-	-0.000 (0.000)	-
Marg. contr. rate	0.098*** (0.029)	-810*** (302)	0.091*** (0.026)	-523 (318)	0.065** (0.030)	342 (426)	0.088*** (0.030)	-469* (276)
Uncond. transfers	-0.00002*** (7D-06)	0.241*** (0.070)	-0.00002*** (6D-06)	0.175** (0.075)	-0.00002*** (7D-06)	0.199** (0.097)	-0.00004*** (8D-06)	0.215*** (0.075)
Fiscal capacity	-0.001 (0.001)	46.0*** (13.5)	-0.002* (0.001)	87.7*** (14.4)	-0.002* (0.001)	95.7*** (15.7)	-0.004*** (0.001)	52.8*** (10.5)
Specific grants for local roads	-	0.995*** (0.044)	-	1.05*** (0.051)	-	1.30*** (0.047)	-	1.12*** (0.037)
Other specific grants	0.00001* (7D-06)	-0.005 (0.071)	0.000 (0.000)	0.025 (0.073)	0.000 (0.000)	0.010 (0.078)	0.00002** (7D-06)	0.004 (0.060)
Debt service	0.00005*** (6D-06)	-0.112 (0.072)	0.00004*** (6D-06)	-0.153** (0.074)	0.00004*** (5D-06)	-0.100 (0.078)	0.00002*** (5D-06)	-0.116** (0.049)
Unemployment	-1.01*** (0.266)	194 (147)	-1.27*** (0.316)	265 (200)	-1.50*** (0.344)	-70.3 (280)	-1.23*** (0.337)	166 (186)
Population (1,000s)	0.0002*** (0.00002)	0.119 (0.272)	0.0002*** (0.00002)	0.309 (0.308)	0.0002*** (0.00002)	1.02** (0.418)	0.0002*** (0.00002)	0.625** (0.274)
Pop. density	0.000 (0.000)	-22.1** (9.25)	0.001 (0.001)	-18.1* (10.1)	0.000 (0.000)	-6.59 (11.6)	0.000 (0.000)	-7.80 (8.17)
% pop. < 16 years	-0.005 (0.012)	-42.8 (120)	-0.004 (0.012)	25.6 (138)	-0.005 (0.012)	40.6 (165)	-0.015 (0.014)	212* (127)
% pop. > 65 years	-0.272** (0.111)	-37.8 (98.3)	-0.187* (0.111)	-112 (109)	-0.075 (0.111)	50.4 (124)	-0.089 (0.118)	140 (88.2)
% church members	-0.132*** (0.028)	-	-0.114*** (0.026)	-	-0.115*** (0.029)	-	-0.109*** (0.032)	-
% church members× unemployment	1.07*** (0.295)	-	1.32*** (0.352)	-	1.57*** (0.383)	-	1.28*** (0.374)	-
% church members× % pop. > 65 years	0.308** (0.123)	-	0.219* (0.123)	-	0.108 (0.123)	-	0.107 (0.130)	-
$R^2$	0.20	0.37	0.20	0.37	0.20	0.43	0.17	0.49
$F$ -tests of excluded IVs:								
$\tau_{-i}$	110.3	215.7	105.4	199.6	73.6	133.9	94.1	115.0
$s_{-i}$	77.7	91.2	95.6	104.1	68.0	65.4	49.8	54.7
Own tax rate	-	5.0	-	5.8	-	6.9	-	5.4
Own public input	7.3	-	8.7	-	7.7	-	16.6	-

Sample includes all municipalities up to independent cities, Nob=1100. Spatial metric for constructing  $\tau_{-i}$  and  $s_{-i}$  is  $W_{pop\ adj}^{15km}$  (see notes in Table 5 for details). Standard errors in parentheses.  $R^2$  is from the third step of the estimation procedure (2SLS after taking account of spatial error correlation).  $F$ -tests of excluded IVs are from first-stage regressions of the 2SLS estimation in the third step of the estimation procedure. Significance levels: \* 10%; \*\* 5%; \*\*\* 1%.

spending level in three out of four cross-sections. The coefficients indicate that a one-Euro increase in neighbors' average spending per capita triggers an increase in a municipality's own per-capita spending on infrastructure between 18 and 51 Cents. Hence, our findings suggest that the municipalities engage in simultaneous tax and public input competition for mobile capital.<sup>11</sup> A second effect that has not been considered in previous work is that

<sup>11</sup>The positive impact of neighbors' spending on a municipality's own spending is unlikely to be driven by technological externalities since the construction and maintenance of major interconnecting roads and

of neighbors' taxes on a municipality's own level of spending on public inputs. In two out of four cross-sections, we find a negative and statistically significant effect, pointing to local governments increasing their per-capita spending on infrastructure by about 7 to 11 Euros per capita in reaction to a one percentage point decrease of their neighbors' average tax rate. Note that the sign of all these effects are in line with the predictions of the model discussed in Section 2.

Interestingly, our results also point to direct interaction between fiscal variables within a community: a one percentage point increase in the statutory tax rate triggers an increase in spending per capita of 32 Euros in 1998 and of 24 Euros in 2000, while in the 2002 cross-section we find a negative effect of about 22 Euros. Moreover, for 1998 and 2000 there is a positive partial effect of public inputs on taxation, indicating that an increase of spending by 100 Euros per capita would result in a tax rate increase of 0.1 to 0.2 percentage points. All these findings support the notion that it is important to account for the fact that not all policy instruments might be adjustable to optimal levels at all points in time.

Besides the evidence on tax and public input competition, there are additional findings that are worth mentioning. Confirming our expectations, the marginal contribution rate positively affects the tax rate, while unconditional transfers exert a negative impact on local taxes. Both findings are in line with Buettner (2006) and support the view that a higher degree of redistribution within a system of fiscal equalization alleviates business tax competition. In addition, there is evidence for a negative impact of the marginal contribution rate on public input provision in two out of four cross-sections. This suggests that fiscal equalization counteracts both tax and public input competition. Furthermore, unconditional transfers are found to positively affect public inputs. An increase of these transfers by one Euro per capita brings about an increase in infrastructure spending per capita of 0.18 to 0.24 Euros. Regarding relative fiscal capacity, our expectations are also confirmed: municipalities with higher capacity set lower tax rates and spend more on public inputs. With respect to the characteristics which are used as instruments in either the tax or the public input equation, we note that spending on local roads strongly reacts

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highways falls into the responsibility the federal government or the states. Our measure of local public input provision thus includes only spending on roads with a very limited potential impact on the productivity of capital invested in other municipalities.



to the amount of specific grants received for that purpose. In addition, we find at least two highly significant variables capturing the religious orientation of the population in all cross-sections.<sup>12</sup> Finally, we note a positive impact of debt service on local taxes and a negative impact on public input provision, and a negative (positive) effect of unemployment (population) on the tax rate.

Regarding the quality of the instruments, we first note that  $\tau_{-i}$  and  $s_{-i}$  are identified by a strong partial correlation with first and second-order spatial lags of exogenous community characteristics, resulting in  $F$ -statistics of the excluded instruments in the corresponding first-stage regressions larger than 50 in general.<sup>13</sup> Hence, we are confident that our identification approach with respect to the spatial effects does not suffer from a weak instruments problem. With respect to a community's own tax rate and public input as endogenous explanatory variables, we first checked the performance of the instruments in the first stage regression in terms of statistical significance. The specific-grants variable is always highly significant in the first-stage regression of public inputs on the set of instruments, with  $t$ -statistics around 10. In the first-stage regression of the tax rate, both the proportion of church members and the interaction with the rate of unemployment are generally significant at the 1% level. However, since the  $F$ -statistics for a community's own tax rate and public input are relatively small, we also checked the critical values for the Stock-Yogo weak identification test. We were able to reject the null that the bias of our IV estimation exceeds 20% of the bias in the corresponding OLS estimation in all cases, lending further support to our identification strategy.

The spatial metric used in the estimations reported in Table 2 assigns 23 neighbors on average to each municipality. In addition, there is substantial variation in the number of neighbors, ranging from one to 54. As a first robustness check of our findings with respect to the definition of neighborliness among municipalities, Table 3 reports results of the same estimations as before, with the metric  $W_{pop\ adj}^{10\ nearest}$  based on the definition of the 10 nearest communities (in terms of physical distance) as neighbors, weighted by population.

A first point to mention is that all main effects from Table 2 are robust to the change in

<sup>12</sup>Note, however, that this finding is not sufficient to rule out a potential problem of weak identification. We comment on this below.

<sup>13</sup>We refer to the 2SLS estimation that is performed as the third step of the estimation procedure.

Table 3: Tax and public input competition, system estimation using  $W_{pop\ adj}^{10\ nearest}$ 

Cross section	1998		2000		2002		2004	
Dependent variable	$\tau$	$s$	$\tau$	$s$	$\tau$	$s$	$\tau$	$s$
Neighbors' tax rate	0.158*** (0.041)	-678* (398)	0.177*** (0.040)	-796* (481)	0.212*** (0.040)	-604 (503)	0.213*** (0.044)	-1412*** (373)
Neighbors' public input	-0.000 (0.000)	0.086 (0.072)	0.000 (0.000)	0.389*** (0.075)	0.00001* (7D-06)	0.134 (0.086)	-0.000 (0.000)	0.217*** (0.080)
Own tax rate	-	3039*** (821)	-	1276 (923)	-	-560 (1066)	-	3283*** (800)
Own public input	0.00002*** (4D-06)	-	0.00001* (4D-06)	-	0.000 (0.000)	-	0.000 (0.000)	-
Marg. contr. rate	0.089*** (0.028)	-774** (303)	0.080*** (0.025)	-470 (323)	0.089*** (0.029)	120 (433)	0.098*** (0.029)	-763*** (289)
Uncond. transfers	-0.00002*** (7D-06)	0.225*** (0.071)	-0.00002*** (6D-06)	0.170** (0.073)	-0.00002*** (7D-06)	0.265*** (0.09)	-0.00004*** (8D-06)	0.304*** (0.080)
Fiscal capacity	-0.001 (0.001)	45.7*** (13.4)	-0.003** (0.001)	85.2*** (14.2)	-0.003** (0.001)	100*** (15.5)	-0.004*** (0.001)	62.4*** (10.6)
Specific grants for local roads	-	0.999*** (0.045)	-	1.05*** (0.051)	-	1.30*** (0.047)	-	1.10*** (0.038)
Other specific grants	0.00001* (7D-06)	-0.004 (0.071)	0.00001* (6D-06)	0.064 (0.073)	0.00001* (6D-06)	0.003 (0.078)	0.00001* (7D-06)	-0.060 (0.062)
Debt service	0.00004*** (6D-06)	-0.096 (0.072)	0.00004*** (6D-06)	-0.089 (0.074)	0.00003*** (5D-06)	-0.153** (0.077)	0.00002*** (5D-06)	-0.194*** (0.048)
Unemployment	-0.961*** (0.264)	189 (140)	-1.10*** (0.312)	187 (183)	-1.18*** (0.334)	93.7 (248)	-0.913*** (0.316)	425*** (157)
Population (1,000s)	0.0002*** (0.00002)	0.169 (0.267)	0.0002*** (0.00002)	0.315 (0.275)	0.0002*** (0.00002)	0.585 (0.3759)	0.0002*** (0.00002)	0.027 (0.272)
Pop. density	0.000 (0.000)	-26.8*** (8.45)	0.000 (0.000)	-22.8** (9.29)	-0.000 (0.000)	-12.7 (10.5)	-0.000 (0.000)	-12.3 (7.56)
% pop. < 16 years	-0.003 (0.012)	-9.84 (118)	-0.000 (0.011)	51.8 (136)	-0.001 (0.012)	80.9 (163)	-0.007 (0.014)	241* (128)
% pop. > 65 years	-0.248** (0.110)	-7.39 (97.0)	-0.198* (0.110)	-52.5 (107)	-0.094 (0.109)	77.1 (120)	-0.025 (0.112)	115 (87.8)
% church members	-0.124*** (0.027)	-	-0.106*** (0.026)	-	-0.100*** (0.028)	-	-0.077** (0.030)	-
% church members× unemployment	1.02*** (0.294)	-	1.16*** (0.349)	-	1.25*** (0.372)	-	0.965*** (0.351)	-
% church members× % pop. > 65 years	0.280** (0.122)	-	0.229* (0.122)	-	0.126 (0.121)	-	0.037 (0.124)	-
$R^2$	0.21	0.38	0.22	0.39	0.22	0.45	0.21	0.48
$F$ -tests of excluded IVs:								
$\tau_{-i}$	77.0	76.1	76.3	63.2	69.0	63.4	88.6	93.7
$s_{-i}$	72.6	78.7	67.1	63.9	38.9	33.7	37.5	36.8
Own tax rate	-	4.9	-	5.8	-	5.7	-	4.1
Own public input	6.9	-	9.5	-	7.1	-	14.7	-

Sample includes all municipalities up to independent cities,  $N_{ob}=1100$ . Spatial metric for constructing  $\tau_{-i}$  and  $s_{-i}$  is  $W_{pop\ adj}^{10\ nearest}$  (see notes in Table 5 for details). Standard errors in parentheses.  $R^2$  is from the third step of the estimation procedure (2SLS after taking account of spatial error correlation).  $F$ -tests of excluded IVs are from first-stage regressions of the 2SLS estimation in the third step of the estimation procedure. Significance levels: \* 10%; \*\* 5%; \*\*\* 1%.

the metric. The effect of neighbors' taxes on a municipality's own tax rate is estimated to be significantly positive but somewhat smaller than before, ranging from 0.16 to 0.21. The impact of neighbors' spending on infrastructure on the local provision of public inputs is of similar size as before, with estimated coefficients ranging from 0.22 to 0.39. The results also confirm the finding that the municipalities take into account the level of taxes among neighbors when choosing their level of spending on the local road network. Even with respect to the strength of the interaction, we do not find any significant difference

compared to the results reported in Table 2. A brief inspection of the evidence regarding the control variables reveals that the effects mentioned above are highly robust to the change in the metric, too.

To some extent, the evidence on tax and public input competition depends on which cross-sections are used for estimation, and it might therefore be useful to have a look on average effects. Table 4 reports the results of a system estimation after applying a between-transformation, i.e. after taking averages of all variables over time. Using  $t = 1, \dots, T$  as the index of time periods, the transformed system reads

$$\bar{\tau}_i = \theta_\tau \bar{s}_i + \lambda_\tau \bar{\tau}_{-i} + \varphi_\tau \bar{s}_{-i} + \beta_\tau \bar{X}_{\tau i} + \bar{u}_i \quad (17)$$

$$\bar{s}_i = \theta_s \bar{\tau}_i + \lambda_s \bar{\tau}_{-i} + \varphi_s \bar{s}_{-i} + \beta_s \bar{X}_{s i} + \bar{v}_i, \quad (18)$$

where  $\bar{\tau}_i = T^{-1} \sum_t \tau_{it}$ ,  $\bar{X}_i = T^{-1} \sum_t X_{it}$ ,  $\bar{\tau}_{-i} = \sum_j w_{ij} \bar{\tau}_j$ , etc. The between-estimations confirm the presence of direct strategic interaction in the choice of taxes and public inputs. Using  $W_{\text{pop adj}}^{15\text{km}}$  as the spatial metric, we find an average direct tax competition effect of 0.263 and a direct public input competition effect of 0.211. With  $W_{\text{pop adj}}^{10 \text{ nearest}}$ , the corresponding point estimates are 0.328 and 0.215, respectively.

The result regarding the impact of neighbors' taxes on own spending on infrastructure is mixed: the null of no interaction cannot be rejected under the metric  $W_{\text{pop adj}}^{15\text{km}}$ , but it is rejected under  $W_{\text{pop adj}}^{10 \text{ nearest}}$  at the 10% level of significance. However, the magnitude of the estimated effect is rather small.

### 3.4 Robustness

The results discussed so far have been derived under specific assumptions with respect to spatial metrics. In related applications it has been shown that the choice of the metric may be of critical importance (Baicker, 2005), and it therefore seems to be warranted to discuss the issue in more detail.

While choosing a metric based on some geographical definition of neighborliness seems to be accepted as a general rule in applications involving local jurisdictions (Buettner, 2001, 2003), no consensus has evolved how to exactly specify the weights. However, as argued

Table 4: Tax and public input competition, system estimation after between-transformation,

Spatial metric Dependent variable	$W_{\text{pop adj}}^{15\text{km}}$		$W_{\text{pop adj}}^{10 \text{ nearest}}$	
	$\tau$	$s$	$\tau$	$s$
Neighbors' tax rate	0.263*** (0.050)	-387 (352)	0.211*** (0.039)	-505* (263)
Neighbors' public input	-0.000 (0.000)	0.328*** (0.081)	-0.000 (0.000)	0.215*** (0.060)
Own tax rate	-	1658*** (568)	-	1591** (632)
Own public input	0.00002*** (5D-06)	-	0.00001*** (5D-06)	-
Marginal contribution rate	0.098*** (0.037)	-372 (278)	0.093** (0.036)	-438 (282)
Unconditional transfers	-0.00003*** (7D-06)	0.261*** (0.054)	-0.00003*** (7D-06)	0.259*** (0.057)
Fiscal capacity	-0.002 (0.002)	87.7*** (11.7)	-0.003** (0.001)	84.7*** (11.8)
Specific grants for local roads	-	1.17*** (0.044)	-	1.17*** (0.044)
Other specific grants	0.00001* (7D-06)	0.016 (0.047)	0.00001* (6D-06)	0.019 (0.048)
Debt service	0.00004*** (6D-06)	-0.166*** (0.050)	0.00004*** (6D-06)	-0.153*** (0.050)
Unemployment	-1.41*** (0.314)	179 (147)	-1.15*** (0.306)	232* (134)
Population (1,000s)	0.0002*** (0.00002)	0.133 (0.203)	0.0002*** (0.00002)	0.198 (0.228)
Pop. density	0.000 (0.000)	-8.43 (6.38)	0.000 (0.000)	-15.8** (6.19)
% pop. < 16 years	-0.010 (0.013)	90.6 (94.7)	-0.004 (0.013)	109 (94.6)
% pop. > 65 years	-0.141 (0.108)	-4.47 (70.3)	-0.135 (0.107)	25.8 (69.6)
% church members	-0.127*** (0.028)	-	-0.109*** (0.027)	-
% church members×unemployment	1.47*** (0.349)	-	1.21*** (0.340)	-
% church members×% pop. > 65 years	0.165 (0.120)	-	0.158 (0.118)	-
$R^2$	0.22	0.48	0.22	0.39
$F$ -tests of excluded IVs:				
$\tau_{-i}$	108.2	149.1	81.2	91.1
$s_{-i}$	124.0	123.8	83.5	79.9
Own tax rate	-	6.3	-	6.0
Own public input	15.9	-	16.5	-

Sample includes observations for all municipalities up to independent cities after between-transformation using years 1998, 2000, 2002, and 2004,  $N_{\text{ob}}=1100$ . Standard errors in parentheses.  $R^2$  is from the third step of the estimation procedure (2SLS after taking account of spatial error correlation).  $F$ -tests of excluded IVs are from first-stage regressions of the 2SLS estimation in the third step of the estimation procedure. Significance levels: \* 10%; \*\* 5%; \*\*\* 1%.

by Conley (1999), in many cases the application itself suggests a certain strategy. In our case, for instance, the significant differences in the jurisdictions' size together with the fact that the key issue driving local governments into strategic interaction is a fiscal externality warrant to include some measure of size. Moreover, there are also technical aspects that need to be considered. As shown in the descriptive statistics (Table 1), the cross-sectional variation of the tax rate is rather limited. Taking averages over neighboring jurisdictions' tax rates will, of course, give a variable with even smaller variation. This problem can

Table 5: Neighbors' tax rates and infrastructure spending for different spatial metrics, year 2000

Spatial metric	Mean		Std. Dev.		Min		Max	
	$\tau_{-i}$	$s_{-i}$	$\tau_{-i}$	$s_{-i}$	$\tau_{-i}$	$s_{-i}$	$\tau_{-i}$	$s_{-i}$
$W_{\text{uniform}}^{15\text{km}}$	0.167	140	0.0030	31.3	0.160	76.3	0.177	253
$W_{\text{inverse}}^{15\text{km}}$	0.167	139	0.0032	33.6	0.159	68.8	0.182	329
$W_{\text{uniform}}^{10 \text{ nearest}}$	0.167	139	0.0034	37.4	0.157	66.0	0.181	332
$W_{\text{inverse}}^{10 \text{ nearest}}$	0.167	139	0.0036	40.6	0.156	66.9	0.182	465
$W_{\text{pop adj}}^{15\text{km}}$	0.171	147	0.0068	28.9	0.160	83.7	0.198	281
$W_{\text{pop adj}}^{10 \text{ nearest}}$	0.169	146	0.0066	35.4	0.156	72.0	0.204	326

$W_{\text{uniform}}^{15\text{km}}$ : Municipalities with distance < 15km defined as neighbors, weights uniform.  $W_{\text{inverse}}^{15\text{km}}$ : Municipalities with distance < 15km defined as neighbors, weights based on inverse distance.  $W_{\text{uniform}}^{10 \text{ nearest}}$ : 10 geographically closest municipalities defined as neighbors, weights uniform.  $W_{\text{inverse}}^{10 \text{ nearest}}$ : 10 geographically closest municipalities defined as neighbors, weights based on inverse distance.  $W_{\text{pop adj}}^{15\text{km}}$ : Municipalities with distance < 15km defined as neighbors, weights based on relative population size.  $W_{\text{pop adj}}^{10 \text{ nearest}}$ : 10 geographically closest municipalities defined as neighbors, weights based on relative population size. All weight matrices are row-standardized.

be expected to become the more severe the more municipalities are, on average, defined as neighbors for a given community. In fact, with sufficiently many communities included in the calculation of neighbors' taxes,  $\tau_{-i}$  will quickly converge towards the regional (or even the statewide) average of taxes. Defining many municipalities as neighbors for a given community will thus result in  $\tau_{-i}$  becoming a poor measure for the tax effort of nearby municipalities.

To exemplify the last point, we have assembled in Table 5 some descriptive statistics for neighbors' average tax rates ( $\tau_{-i}$ ) and neighbors' expenditures on infrastructure ( $s_{-i}$ ) according to different spatial metrics (based on data for the year 2000).

The first four rows depict statistics for spatial metrics that take either the municipalities within a distance of up to 15km or the 10 geographically closest municipalities to be neighbors of a given municipality. Irrespective of whether we take the weights of neighbors to be uniform or to be defined based on the inverse of the great circle distance, the variable capturing the average tax rate of neighbors shows very limited variation. With uniform weights assigned to municipalities within a distance up to 15km, for instance, the variation in neighbors' average tax rate is actually modest, with a minimum of 0.16 and a maximum of 0.177. However, if we account for asymmetries in population size (last two rows), the variation in the resulting series is significantly higher. Note that, due to higher variation in local expenditures per capita, the computation of neighbors' spending on infrastructure does not seem to be affected by the problem of quick convergence towards regional or

Table 6: Selected parameter estimates for different spatial metrics

I													
Year		$W^{15km}_{uniform}$					$W^{15km}_{inverse}$						
	$\lambda_\tau$	$\varphi_\tau$	$\theta_\tau$	$\lambda_s$	$\varphi_s$	$\theta_s$	Year	$\lambda_\tau$	$\varphi_\tau$	$\theta_\tau$	$\lambda_s$	$\varphi_s$	$\theta_s$
1998	0.68***	-	0.00001***	-3643***	0.22**	5307***	1998	0.73***	-	0.00001***	-2497*	0.20**	3584***
1999	0.72***	-	-	-	0.32***	-	1999	0.73***	-	-	-	0.31***	-
2000	0.77***	-	0.00001*	-3225**	0.53***	4127***	2000	0.74***	-	-	-	0.53***	-
2001	0.72***	-	-	-3389*	0.38***	4194**	2001	0.75***	-	-	-	0.32***	3105*
2002	0.85***	-	-	-	0.38***	-	2002	0.87***	-	-	-	0.31***	-
2003	0.71***	0.00001**	-	-7091***	-	6658***	2003	0.77***	0.00001**	-	-10092***	-	9554***
2004	0.94***	-	-	-6560***	0.21**	7378***	2004	0.93***	-	-	-7963***	-	8549***
II													
Year		$W^{10}_{nearest}_{uniform}$					$W^{10}_{nearest}_{inverse}$						
	$\lambda_\tau$	$\varphi_\tau$	$\theta_\tau$	$\lambda_s$	$\varphi_s$	$\theta_s$	Year	$\lambda_\tau$	$\varphi_\tau$	$\theta_\tau$	$\lambda_s$	$\varphi_s$	$\theta_s$
1998	0.57***	-	0.00001**	-	-	-	1998	0.55***	-	0.00001**	-	-	-
1999	0.54***	-	-	-	0.19***	-	1999	0.53***	-	-	-	0.17***	-
2000	0.54***	-	-	-	0.46***	-	2000	0.53***	-	-	-	0.42***	-
2001	0.56***	0.00001*	-	-	0.24***	-2505*	2001	0.57***	0.00001*	-	-	0.20***	-
2002	0.70***	0.00001**	-	-	0.22***	-	2002	0.71***	0.00001**	-	-	0.21***	-
2003	0.58***	0.00001**	0.00001*	-	-	-2765*	2003	0.60***	0.00001*	-	-	-	-
2004	0.77***	-	0.00001*	-6812***	0.18**	7703***	2004	0.78***	-	0.00001*	-8853***	0.13*	9613***
III													
Year		$W^{15km}_{pop adj}$					$W^{10}_{nearest}_{pop adj}$						
	$\lambda_\tau$	$\varphi_\tau$	$\theta_\tau$	$\lambda_s$	$\varphi_s$	$\theta_s$	Year	$\lambda_\tau$	$\varphi_\tau$	$\theta_\tau$	$\lambda_s$	$\varphi_s$	$\theta_s$
1998	0.19***	-	0.00001***	-731**	0.17*	3190***	1998	0.15***	-	0.00001***	-678*	-	3039***
1999	0.20***	-	0.00001***	-741*	0.25***	-	1999	0.14***	-	0.00001**	-	0.14*	-
2000	0.20***	-	0.00001***	-1005**	0.50***	2396***	2000	0.17***	-	0.00001*	-796*	0.38***	-
2001	0.22***	-	-	-862**	0.37***	1702*	2001	0.15***	-	-	-	0.25***	-
2002	0.27***	-	-	-	0.23*	-2176**	2002	0.21***	0.00001*	-	-	-	-
2003	0.22***	-	-	-	0.40***	-	2003	0.18***	-	-	-	-	-
2004	0.31***	-	-	-	-	-	2004	0.21***	-	-	-1412***	0.21***	3283***

For definitions of spatial metrics, see Table 5. Bars (-) indicate that the coefficient is not statistically different from zero at the 10% level of significance. \* significant at 10% level; \*\* significant at 5% level; \*\*\* significant at 1% level.



statewide averages.

Based on the preceding discussion, we expect the estimates regarding the impact of  $\tau_{-i}$  to critically depend on the choice of the spatial metric. In contrast, the estimates regarding the coefficient of  $s_{-i}$  should be more robust to the definition of neighbors. To check to what degree this presumption is supported by our data, we estimated our system of reaction functions using the different spatial metrics. Table 6 gives an overview on the estimated coefficients of interest for a number of cross-sections.

We note that using  $W_{\text{uniform}}^{15\text{km}}$ ,  $W_{\text{inverse}}^{15\text{km}}$ ,  $W_{\text{uniform}}^{10 \text{ nearest}}$  and  $W_{\text{inverse}}^{10 \text{ nearest}}$  results in very large estimates of  $\lambda_\tau$  compared to  $W_{\text{pop adj}}^{15\text{km}}$  and  $W_{\text{pop adj}}^{10 \text{ nearest}}$ . This is well in line with our expectations, as the variation in  $\tau_{-i}$  tends to be low (recall that, with the weight matrix approaching a matrix of uniform weights for *all* other municipalities,  $\tau_{-i}$  becomes a constant measuring the average tax rate among all communities). Note that for our system of equations to be stable,  $\lambda_\tau$  is required to be smaller than one in absolute value. There are two estimations based on the 2004 cross-section where this requirement is barely met, adding further doubt about the appropriateness of spatial metrics that define ‘large’ sets of neighbors and that do not account for the municipalities’ relative population size. It is also worth mentioning that the estimate for the interaction effect in public input provision,  $\varphi_s$ , is much more robust to changes regarding the spatial metric. Noting that the variation in spending on infrastructure is much higher than the variation in tax rates, and that defining a composite neighbor from a large set of communities should therefore be less of a technical problem, it is reassuring that the conclusions regarding public input competition are not critically affected by the choice of a spatial metric that defines either smaller or larger sets of neighbors.

## 4 Conclusions

Although it seems natural to think of governments’ choices regarding taxes and public inputs as alternative means to attract mobile capital, most of the literature on fiscal competition has focused either on taxes or on expenditures. This study offers a comprehensive treatment of tax and public input competition, with a focus on the strategic interaction between governments in simultaneously choosing both policy instruments. We use a sim-

ple theoretical model to characterize the two-dimensional system of tax and public input reaction functions. We then test the predictions of the model with respect to the strategic behavior of governments. Using a systems estimator for spatially interrelated equations, we show that the fiscal policies of local jurisdictions in Germany are well in line with the model's predictions.

Our findings suggest that the behavior of local jurisdictions is much more complex than described by the earlier empirical literature on fiscal competition. In particular, the estimation results of our system of interrelated equations show a positive and significant direct interaction effect in the local business tax rate. Municipalities facing competition by low-tax jurisdictions thus set lower taxes than municipalities with high-tax neighbors. Secondly, the local governments also adjust their level of spending on infrastructure towards the average level among neighboring jurisdictions. For our preferred specifications, the direct interaction effect in public input provision is statistically different from zero in 10 out of 14 cross-sections, and it tends to be larger than the direct interaction effect in taxes. Moreover, treating taxes and public inputs as alternative means to attract capital reveals that the municipalities react to competition in a rather flexible way: if neighbors lower their taxes, a municipality not only adjusts its own tax rate, but also increases its level of public input provision. Finally, we demonstrate that our results depend on the choice of the spatial metric in a predictable way, and that all main results are robust across various cross-sections.

Several lines of further research seem to be promising. First of all, it would be interesting to further explore the underlying nature of fiscal competition among local governments by further analyzing what drives the regional co-movement in tax rates and spending levels. Is it competition resulting from fiscal externalities or are we rather observing yardstick competition? This could be done by testing empirically whether variations in the observed policy instruments actually trigger capital flows between jurisdictions. Furthermore, it would be worthwhile to compare our results to evidence regarding tax and expenditure competition from other countries. Depending on the institutional environment, taking into account different policy instruments could yield further insights into the rather complex process of fiscal policy decision making at the local level. For instance, with respect to the US, our findings suggest to treat local property taxes and local expenditures for public

schools as well as public safety as jointly determined endogenous variables. Moreover, we think that some of the recently proposed improvements regarding spatial estimation techniques can fruitfully be applied in cases that are of interest both from an academic and from a policy perspective. Further advances towards estimation techniques for systems of interrelated equations and panel data would therefore be highly welcome.

## References

- BAICKER, K. (2005): “The spillover effects of state spending,” *Journal of Public Economics*, 89, 529–544.
- BAYINDIR-UPMANN, T. (1998): “Two games of interjurisdictional competition when local governments provide industrial public goods,” *International Tax and Public Finance*, 5, 471–487.
- BÉNASSY-QUÉRÉ, A., N. GOBALRAJA, AND A. TRANNOY (2007): “Tax and public input competition,” *Economic Policy*, 22(50), 385–430.
- BERGSTROM, T. E., AND R. P. GOODMAN (1973): “Private demands for public goods,” *American Economic Review*, 63, 280–296.
- BRUECKNER, J., AND L. SAAVEDRA (2001): “Do local governments engage in strategic property-tax competition?,” *National Tax Journal*, 54, 203–229.
- BUCOVETSKY, S. (2005): “Public input competition,” *Journal of Public Economics*, 89, 1763–1787.
- BUCOVETSKY, S., AND M. SMART (2006): “The efficiency consequences of local revenue equalization: Tax competition and tax distortions,” *Journal of Public Economic Theory*, 8(1), 199–144.
- BUETTNER, T. (1999): “Determinants of tax rates in local capital income taxation: A theoretical model and evidence from Germany,” *Finanzarchiv*, 56(363–388).
- (2001): “Local business taxation and competition for capital: The choice of the tax rate,” *Regional Science and Urban Economics*, 31, 215–245.

- (2003): “Tax base effects and fiscal externalities of local capital taxation: Evidence from a panel of German jurisdictions,” *Journal of Urban Economics*, 54, 110–128.
- (2006): “The incentive effect of fiscal equalization transfers on tax policy,” *Journal of Public Economics*, 90, 477–497.
- CONLEY, T. G. (1999): “GMM estimation with cross sectional dependence,” *Journal of Econometrics*, 92, 1–45.
- CRAIG, S. G. (1987): “The impact of congestion on local public good production,” *Journal of Public Economics*, 32, 331–353.
- DEVEREUX, M. P., B. LOCKWOOD, AND M. REDOANO (2008): “Do countries compete over corporate taxes?,” *Journal of Public Economics*, 92, 1210–1235.
- EGGER, P., M. KOETHENBUERGER, AND M. SMART (2007): “Do fiscal transfers alleviate business tax competition? Evidence from Germany,” CESifo Working Paper No. 1955, Munich.
- FERNALD, J. G. (1999): “Roads to prosperity? Assessing the link between public capital and productivity,” *American Economic Review*, 89, 619–638.
- GOMES, P., AND F. POUGET (2008): “Corporate tax competition and public capital stock,” unpublished manuscript.
- HAYASHI, M., AND R. BOADWAY (2001): “An empirical analysis of intergovernmental tax interaction: The case of business income taxes in Canada,” *Canadian Journal of Economics*, 34, 481–503.
- HINDRIKS, J., S. PERALTA, AND S. WEBER (2008): “Competing in taxes and investment under fiscal equalization,” *Journal of Public Economics*, 92, 2392–2402.
- KEEN, M., AND M. MARCHAND (1997): “Fiscal competition and the pattern of public spending,” *Journal of Public Economics*, 66, 33–53.
- KELEJIAN, H. H., AND I. R. PRUCHA (1999): “A generalized moments estimator for the autoregressive parameter in a spatial model,” *International Economic Review*, 40, 509–533.

- (2004): “Estimation of simultaneous systems of spatially interrelated cross sectional equations,” *Journal of Econometrics*, 118, 27–50.
- KOETHENBUERGER, M. (2002): “Tax competition and fiscal equalization,” *International Tax and Public Finance*, 9, 391–408.
- MATSUMOTO, M. (2000): “A tax competition analysis of congestible public inputs,” *Journal of Urban Economics*, 48, 242–259.
- MINTZ, J., AND H. TULKENS (1986): “Commodity tax competition between member states of a federation: Equilibrium and efficiency,” *Journal of Public Economics*, 29, 133–172.
- PETCHEY, J., AND P. SHAPIRO (2008): “Equilibrium in fiscal competition games from the point of view of the dual,” forthcoming in: *Regional Science and Urban Economics*.
- TAYLOR, L. (1992): “Infrastructural competition among jurisdictions,” *Journal of Public Economics*, 49, 241–259.
- WILDASIN, D. (1988): “Nash equilibria in models of fiscal competition,” *Journal of Public Economics*, 35, 229–240.
- WILDASIN, D. E. (1991): “Some rudimentary ‘duopoly’ theory,” *Regional Science and Urban Economics*, 21, 393–421.
- WILSON, J. D. (1986): “A theory of interregional tax competition,” *Journal of Urban Economics*, 19, 296–315.
- WILSON, J. D. (1991): “Tax competition with interregional differences in factor endowments,” *Regional Science and Urban Economics*, 21, 423–452.
- ZODROW, G., AND P. MIESZKOWSKI (1986): “Pigou, Tiebout, property taxation and the underprovision of local public goods,” *Journal of Urban Economics*, 19, 356–370.

# Appendix

## The system (7) under symmetry

Plugging in the various derivatives into (7) gives

$$\begin{pmatrix} -\frac{g^2+3b}{4b^2} & \frac{g^2+2bkg+b}{4b^2} \\ \frac{g^2+2bkg+b}{4b^2} & -\frac{g^2+b^2k^2+b(4gk-1)}{4b^2} \end{pmatrix} \begin{pmatrix} dt_i \\ dg_i \end{pmatrix} = \begin{pmatrix} -\frac{g^2+b}{4b^2} & \frac{g^2+b}{4b^2} \\ \frac{g^2+2bkg-b}{4b^2} & -\frac{g^2-2bkg+b}{4b^2} \end{pmatrix} \begin{pmatrix} dt_j \\ dg_j \end{pmatrix}. \quad (\text{A.1})$$

## The symmetric equilibrium

In order to derive the symmetric Nash equilibrium, we form the first order conditions of (6) with respect to the tax rate,

$$t_i = \frac{(g_i^2 + b)(bk + g_i - g_j + t_j)}{g_i^2 + 3b}. \quad (\text{A.2})$$

Having done that for each country, we invoke symmetry in  $g$ , giving us a symmetric tax rate

$$t^o = \frac{1}{2}(b + g^2)k. \quad (\text{A.3})$$

In the next step, we proceed analogously for public inputs, i.e. we form the first order conditions of (6) with respect to public inputs, then impose symmetry in  $t$ , giving us

$$g^o = \frac{\sqrt{b^2k^4 + 4bk^2 + 8tk} - bk^2}{2k}. \quad (\text{A.4})$$

Combining (A.3) and (A.4) provides us with the Nash equilibrium values of

$$g^* = 2/k, \quad t^* = (bk^2 + 4)/(2k). \quad (\text{A.5})$$

## Sufficient conditions

We have to check that the second derivatives of the welfare function with respect to own instruments are negative at the symmetric equilibrium. To see this, note that

$$\left. \frac{\partial^2 U_i}{\partial t_i \partial t_i} \right|_{g=g^*} = -\frac{3b + \frac{4}{k^2}}{4b^2} < 0 \quad (\text{A.6})$$

and

$$\left. \frac{\partial^2 U_i}{\partial g_i \partial g_i} \right|_{g=g^*} = -\frac{b(bk^2 + 7) + \frac{4}{k^2}}{4b^2} < 0. \quad (\text{A.7})$$

Note furthermore that the Hessian determinant evaluated at the Nash equilibrium is

$$|H|_{g=g^*} = \frac{3k^2}{16b}. \quad (\text{A.8})$$

Since this expression is positive, all sufficient conditions for a maximum are met.

## Stability

To address the issue of stability of the symmetric equilibrium, we take a look at the slopes of the reaction functions, given in (10) and (11). There, we see that  $(bk^2 - 4)/3bk^2$ ,  $-(bk^2 - 4)/3bk^2$ ,  $-4/3bk^2$  and  $4/3bk^2$  are all less than one in absolute value for any  $b > 4/k^2$ , the condition imposed in the main text. Note furthermore that due to the symmetric marginal reaction of capital to both instruments from (4), it is possible to determine the slope of a ‘net policy response function’ by adding the absolute values of the slopes of both of  $i$ ’s reactions to a marginal change in one of  $j$ ’s instruments. They add to  $1/3$ , demonstrating stability in the policy response around the symmetric Nash equilibrium. To give an example, a marginally higher public input in  $j$  triggers a reaction in  $i$ ’s tax instrument with slope  $-(bk^2 - 4)/3bk^2$  and a reaction in the public input with slope  $4/3bk^2$ . From (3), we know that the tax response affects capital in just the opposite direction than the public input response, so adding both terms in absolute values gives us the combined ‘policy response’ slope of  $1/3$ .



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