Vertical Competition, Horizontal Competition and Mobile Capital: An Empirical Investigation

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Abstract

The American states and their constituent local governments each levy taxes on mobile business capital. State-level taxes include the corporate income, corporate franchise and property taxes, while local-levies are dominated by the property tax. This structure of capital taxation gives rise to a web of possible tax competition interactions. Vertical tax competition may arise as a state and its local governments impose capital taxes on a common tax base, while horizontal competition over mobile capital may take place across states, across local governments in different states, and between local governments in one state and other states. Using spatial econometrics, this paper examines these vertical and horizontal interactions using U.S. data for the period 2000-2006. The empirical application is unique in its focus on multiple federations and allowance for both intra-federation competition and inter-federation competition. We find negative within-federation vertical reaction functions for both states and their localities indicating that state and local government capital tax rates are strategic substitutes. Local tax rates, on the other hand, are found to react positively to other-state capital tax rates and to the tax rates of localities in other states. State tax rates are not affected by the tax rates of localities in other states, but they do react positively to the tax rates of neighboring states. We also offer evidence that states behave as Stackelberg leaders in the setting of capital taxes on business.

JEL classification: H25; H7; R1; R5
Keywords: Vertical competition, horizontal competition, capital taxation

1. **Introduction**

An extensive theoretical and empirical literature has emerged to explore competition among governments for mobile factors of production, with forms of competition that can exist between various levels and across similar levels of government. For example, when several levels of government have the ability to impose taxes on an identically-defined base, the competition can occur between same-level governments as well as between different levels of government. The theoretical literature on horizontal competition among same-level governments shows that governments set tax rates on mobile factors that are suboptimally low as governments ignore the negative externality they have on competing jurisdictions' tax bases when reducing their own tax rates.[1]

Early models of horizontal tax competition typically ignored the presence of a higher or lower level government. Some of the more recent literature has investigated these vertical interactions that occur between different levels of government. The strategic behavioral interaction in this setting occurs as different levels of government seek to impose taxes on a common tax base. Given mobility of the base, a tax increase by one level of government will reduce the size of the tax base for other levels of government in the same fiscal hierarchy. The other level governments may respond to the decreased tax base by increasing their own tax rate to maintain tax revenues, or alternatively, decreasing their own tax rate in an attempt to limit the flight of the tax base from the jurisdiction. Because of these possible behavioral responses, the theoretical literature finds an ambiguous sign on the reaction function between levels of government.[2]

[1] See Wilson (1999) for a review of the theoretical literature on tax competition.
[2] See Keen (1998) for a review of vertical tax competition.

This paper uses spatial econometrics to explore both vertical and horizontal tax competition over mobile capital by considering state-level and local-level capital taxes in the U.S. for the period 2000-2006. The empirical application is unique in its focus on multiple federations and allowance for intra-federation competition and inter-federation competition. The models accommodate horizontal competition across (aggregate) local governments and across individual states, vertical competition between local governments and their own state, and vertical competition between own-state local governments and other state governments.

We consider the corporate income and franchise taxes, as well as state business property taxes, as the primary taxes on mobile capital at the state level. At the local level we focus on the business share of the property tax. While the taxes on mobile capital have a different formal structure at the state and local levels, they nonetheless fall on capital. There is ample anecdotal evidence of horizontal tax competition across states and localities using these tax instruments. For example, 44 states relied on the equally-weighted three-factor corporate income apportionment formula in 1989, but by 2008, 34 states had adopted some variant of a more heavily sales-weighted apportionment formula. Tax competition must receive part of the responsibility for the declining role that the state corporate income tax has played in state finances dating back to the mid 1980s. At the substate level it is common to observe horizontal competition through large and often controversial property tax concessions for both new and existing industry. In 2006, for example, the state of Georgia granted tax abatements totaling $130 million to Kia in exchange for the commitment to create nearly 3,000 jobs.[3] More recently, Tennessee provided over $500 million in tax and other concessions to secure the Volkswagen plant location in Chattanooga. While economists are now exploring vertical tax competition, this issue has received scant attention among policymakers and the public.

[3] See http://www.themanufacturer.com/us/detail.html?contents_id=4144. Accessed April 19, 2010.

2. Literature

The horizontal tax competition literature is much more extensive than the research on vertical competition, in part a reflection of long-standing concerns over the economic, tax revenue and efficiency consequences of interjurisdictional competition. Primary focal areas of the theoretical literature on horizontal competition are the mobility of the tax base in response to tax rates and the strategic interactions between governments in the setting of the rates. Many recent empirical studies have examined strategic interactions by regressing a jurisdiction's tax rate on the tax rates of neighboring (typically contiguous) jurisdictions. While these empirical models do not directly measure tax base mobility and horizontal externalities, the results generally indicate that states do not set tax rates in isolation.[4] Research has found that in some cases the policy reaction functions are positive, indicating that the tax policies of same-level governments are strategic complements, and in other instances negative, indicating that same-level government tax policies are strategic substitutes.

While these findings indicate that governments behave strategically, a mobile tax base is not the only underlying behavior that may lead to the observed empirical relationships. Instead the interactions may be the result of yardstick competition, where constituencies decide whether or not to vote for a politician based on their state's tax rates compared with other states' rates. Thus, politicians may consider other states' tax rates when setting their own rate. Importantly, Revelli (2003) points out that the strategic interaction that appears to occur between same level governments may result from common reactions to the upper level government, rather than actual strategic interaction among lower level governments. Thus it is important to consider the upper level government even if one is only interested in horizontal interactions among lower level governments.

[4] See Brueckner (2003) and Revelli (2005) for surveys of empirical tax competition research.

A body of literature is now emerging focused on understanding both horizontal and vertical externalities and their interactions in a federal setting. This literature includes a number of empirical studies that have sought to examine vertical reaction functions. Besley and Rosen (1998), for example, examine gasoline and cigarette tax rate determination by states and the federal government in the U.S. They find that an increase in the federal excise tax on these goods leads states to increase their tax rates as well. Devereux, Lockwood and Redoano (2007) extend Belsey and Rosen to account for horizontal and vertical competition over gasoline and cigarette taxes and similarly find positive vertical reaction functions. Fredriksson and Mamum (2008), on the other hand, find that state cigarette taxes fall in response to higher federal excise taxes. Esteller-More and Sole-Olle (2001) test for the presence of both horizontal and vertical externalities using the U.S. and state personal income tax rates and find that states respond positively to an increase in the federal income tax rate. Hayashi and Boadway (2001) examine the impact of externalities created by the federal and provincial governments in the Canadian corporate tax setting and find that provincial business tax rates respond negatively to the federal business tax rate. Karkalakos and Kotsogiannis (2007) extend the analysis of Hayashi and Boadway to accommodate all Canadian provinces, along with equalization transfers from the federal government. Unlike Hayashi and Boadway, they find positive vertical reaction functions.

One common feature of the growing research on vertical tax competition is that only one federation is considered when in practice there is likely inter-federation competition. With only one exception, these studies examine federations where there is *intra*-federation horizontal competition among lower level governments and where the local governments may also compete with the single upper level government in the setting of tax rates. For example, Hayashi and Boadway (2001) do not allow for competition between the Canadian and U.S. federal

governments or competition between the subnational governments of Canada and the U.S. Brulhart and Jametti (2006), on the other hand, consider both vertical and horizontal competition in the multi-federation context of Swiss cantons and their constituent municipalities. However, their analysis does not accommodate inter-federation competition on the part of either cantons or municipalities even though such competition likely exists. Karkalakos and Kotsogiannis (2007) offer an exception by accounting for the corporate income taxes of U.S. border states. They find evidence of negative horizontal externalities for some Canadian provinces.

Our research contributes to the literature in several key ways. First, we jointly estimate vertical and horizontal reaction functions that account for lagged behavioral responses, and alternatively, simultaneity. Second, we conduct our study in the presence of multiple federations allowing us to control for inter-federation competition among upper and lower level governments which could have an effect on intra-federation competition. Third, we offer the first empirical examination of vertical reaction functions for capital taxes in the U.S.

Our results are consistent and robust across an array of model specifications. In particular, we find that within-federation vertical reaction functions are negative for both states and their localities indicating that state and local government capital tax rates are strategic substitutes. This is of particular importance to policymakers as it suggests that if one level of government lowers rates to attract capital, the other level of government may respond with a tax rate increase to make use of some of the new tax capacity. Inter-jurisdictional competition takes a very different form. Local tax rates react positively to both other-state capital tax rates and to the tax rates of localities in other states. State tax rates, on the other hand, are not affected by the tax rates of localities in other states, but they do react positively to the tax rates of neighboring

states. This result may reflect a yardstick effect whereby other-state rates are more visible than local tax rates in other states.

3. Conceptual Framework

To guide our empirical analysis, we outline of a general theoretical construct that builds on Hayashi and Boadway (2001) and Karkalakos and Kotsogiannis (2007). We envision a setting with a large number of federations (states) $i = 1,\ldots I$, where each federation contains two levels of government (state and local).[5] Competitive firms employ capital K_i to produce output using well-behaved production functions $F_i(K_i)$. Both the state and local governments in each federation i fund public good provision with source-based taxation of mobile capital. Governments are initially assumed to engage in Nash behavior in setting capital tax rates. This general structure produces a web of possible tax policy interactions. Vertical externalities arise as each federation and its constituent local government seek to tax a common base. Horizontal competition may arise across local governments in different states and between states. A form of "diagonal" horizontal competition may also exist between state governments in one federation and local governments in other federations.

Each state imposes an ad valorem tax T_i on K_i while the locality imposes tax at the rate τ_i on K_i. The return to capital ρ, along with federation and local tax rates, helps guide mobile capital such that

$$\partial F_i/\partial K_i - \tau_i - T_i = \rho \qquad \text{for } i = 1,\ldots I \qquad (1)$$

For any state i, $\partial K_i/\partial \tau_i < 0$; $\partial K_i/\partial \tau_j > 0, j \neq i$. Similarly, higher state tax rates are expected to repel capital: $\partial K_i/\partial T_i < 0, \forall i$ while $\partial K_i/\partial T_j > 0\ j \neq i$.

[5] We assume that there is only one local level government in each state. For our empirical approach, this translates to examining the interaction between the state level government and an average local government within the state.

Following Hayashi and Boadway (2001) we assume a well-behaved local government objective function over revenue and the local capital stock,

$$\max_{\tau_i} \; w(\tau_i(F(K_i(\cdot)), K_i(\cdot)), \qquad (2)$$

where $K_i(\cdot)$ includes tax rates for all local jurisdictions including itself, all local rates in all other federations and the range of federation tax rates. The solution to (2) yields the optimal own-jurisdiction local tax rate $\tau_i^*(\cdot)$. Reaction functions $r_i = r(\cdot)$ can in principal be derived from $\tau_i^*(\cdot)$. These reaction functions would have as arguments the tax rates of all jurisdictions other than i. In a general setting such as that presented here, these reaction functions can be expected to have ambiguous signs.

The federation analog to (2), assuming Nash behavior and optimization over revenue and the capital stock is

$$\max_{T_i} \; W(T_i(F(K_i(\cdot)), K_i(\cdot)), \qquad (3)$$

where the range of tax instruments for all federations and all local taxing jurisdictions in all federations is suppressed in $(\cdot)$. From the solution T_i^*, reaction functions $R_i = R(\cdot)$ can be derived. Like their local counterparts $r_i = r(\cdot)$, we would expect ambiguous signs for the federation-level reaction functions.

The general static framework presented here assumes contemporaneous decisionmaking. Policy lags and leader-follower behavior may each have an impact on timing and strategic behavior. Policy lags might arise, for example, due to differences in the timing of federation versus local government decisionmaking as well as policy implementation. Similarly, local governments in different federations may be on different time paths for legislative action. Stackelberg leader behavior on the part of states rather than Nash behavior would suggest a

sequential process where the local government sets its tax policy with a one-period lag.[6] We consider these timing issues in greater detail in the empirical section below.

4. Econometric Framework

In order to test empirically whether state and local governments behave strategically in setting tax rates on capital while taking into consideration inter-federation competition, we posit contemporaneous reaction functions building on the discussion above:

$$\tau_{it} = \gamma T_{it} + \rho \sum_{j \neq i} \omega_{ij} \tau_{jt} + \alpha \sum_{j \neq i} \omega_{ij} T_{jt} + \sum_{k} \theta_k Z_{k,it} + \varepsilon_{it} \quad (4)$$

$$T_{it} = \delta t_{it} + \beta \sum_{j \neq i} \omega_{ij} T_{jt} + \psi \sum_{j \neq i} \omega_{ij} \tau_{ij} + \sum_{k} \lambda_k X_{k,it} + \mu_{it} \quad (5)$$

where τ and T are the local and state tax rates, respectively, and the subscripts i and t represent state and year. Z and X are vectors of control variables. This is a spatial autoregressive (SAR) model that includes spatial lags for both state and local tax rates. We assume that states and their local governments compete against the same set of states and those states' local governments.

The inter-federation interactions in equations (4) and (5) are measured by the terms $\sum_{j \neq i} \omega_{ij} \tau_{jt}$ and $\sum_{j \neq i} \omega_{ij} T_{jt}$, where ω_{ij} defines which states are neighbors and is specified a priori. The model presented above accounted for interactions across all jurisdictions, while in practice the spatial weight term, ω_{ij}, can take a number of forms. The form of ω_{ij} must be guided by conceptual considerations. We begin with variants of contiguity for two reasons. First, contiguity is likely to be more important than alternative definitions of neighbors from the perspective of yardstick competition because of the flow of information (television, radio and print media) and people (commuters and shoppers) across state borders. Second, one might

[6] Hayashi and Boadway (2001) and Karkalakos and Kotsogiannis (2007) consider Nash models, as well as Stackelberg models where the federation is the policy leader and the provinces are followers.

expect the geographic mobility of capital to be somewhat constrained, especially for capital used in the production of goods and services that are sold regionally. We also consider a distance-weighted contiguity definition and an inverse-distance measure of the neighbor set.

The contiguity matrix, which is similar to that used in much of the tax competition literature, is given by $\omega_{ij} = 1$ if states *i* and *j* are contiguous and zero otherwise. The matrix is row-standardized, meaning the sum of the weights equals one, so the term $\sum_{j \neq i} \omega_{ij} \tau_{jt}$ becomes the average of the neighbors' local government tax rates. The same process applies to the state-level weight matrix and state tax rates $\sum_{j \neq i} \omega_{ij} T_{jt}$. The distance-contiguity matrix continues to define only the states that border a state as neighbors, but the states are given different weights based upon the physical distance between the largest cities of the states. States that are closer are given more weight and the matrix is row-standardized. Our final neighbor definition relaxes the contiguity assumption. In the inverse-distance weighting scheme, we assume that all 48 contiguous states are "neighbors," but states place more weight on those states that are in closer proximity.

Several econometric issues raised by Brueckner (2003) and Revelli (2005) must be addressed before estimating equations (4) and (5). First, because models of horizontal tax competition hypothesize that jurisdictions set tax rates strategically, the neighbors' tax rates on the right hand side of the equations are endogenous. Simple ordinary least squares (OLS) estimation would lead to inconsistent parameter estimates. The common way to overcome this problem in the literature is to lag the neighbors' tax rates by one period. Not only does this eliminate endogeneity, but it may also be more realistic to assume that the interaction occurs with a one-year policy-adoption lag. OLS estimates are consistent using this approach.

Alternatively, if the policy interaction occurs simultaneously, so that the neighbors' tax rates are contemporaneous rather than lagged, the literature commonly uses instrumental variables (IV) methods. Following Brueckner (2003), this second approach involves regressing the neighbors' tax rates on the spatially-weighted explanatory variables.

Another problem with estimating equations (4) and (5) is the potential endogeneity of the other level of government's tax rate due to vertical competition. One way to deal with the potential endogeneity is to lag the other level of government's tax rate one period. Similar to the horizontal interaction, the one-year lag might be more realistic in the timing of tax policy decisions. As discussed more fully below, we assume that the horizontal and vertical interactions of tax policy decisions occur with a one year time period lag.

As discussed in Cameron, et al. (2006), appropriate inference of the results in the presence of within-state autocorrelation of the errors requires clustering of the standard errors by state. In addition, if there is any geographic-based correlation then we may have within-year correlation of errors across states, so standard errors should also be clustered by year. Because our data show evidence of correlation across states and across time, we utilize the multi-way clustering of standard errors proposed by Cameron et al. (2006) in which we cluster standard errors by state and year.[7]

5. Data

The effects of horizontal and vertical competition are examined in a panel setting with multiple federations, while allowing for inter-federation competition. We consider a setting where each of the 48 continental states of the U.S. is thought of as a federation, consisting of one upper level government (the state) and one lower level government (the statewide aggregate of

[7] See Shan (2010) for a recent application of the multi-way clustering of standard errors as proposed by Cameron et al. (2006).

local governments).[8] Vertical competition may occur between the state and its local governments and inter-federation competition may take place between states, between localities and between states and other states' local governments. A panel of the 48 contiguous states for the years 2000-2006 was developed for the analysis.

Businesses confront several taxes at the state level that fall on capital, including the corporate income and corporate franchise taxes, and state-levied property taxes that fall more generally on business activity. One option for specifying these state-level tax burdens would be to use nominal tax rates. However, nominal rates fail to capture the nuances of business taxes that may affect the effective tax rate, from the nature of loss carryforwards to the presence of economic development incentives. Also, this approach requires three or more nominal tax rates at the state level. We take an alternative approach that focuses on a proxy for the effective state capital tax rate. This effective rate is calculated by dividing the sum of state-level business property tax revenue (see below), state corporate income tax revenue and state business license (including franchise tax) revenue by state personal income. For the period of our analysis, corporate income taxes range from a low of 67.5 percent of total state capital taxes to a high of 73.7 percent across the years. The effective state capital tax rate falls by nearly 7 percent between 2000 and 2006.

The property tax is the largest local tax on capital. For comparability with the state tax variable, the average effective local capital tax burden in each state is calculated by dividing local business property tax revenues by state personal income. Annual series provided by the U.S. Bureau of the Census are one source of data on property tax revenues,[9] but these data include both residential and business property tax collections. To address this problem, we take

[8] This structure does not allow us to examine intra-federation horizontal reaction functions, i.e., interactions between in-state local governments, but we attempt to control for intra-federation competition as discussed below.
[9] See http://www.census.gov/govs/www/estimate.html for example. Accessed April 19, 2010.

advantage of a unique data source on business-specific state and local property tax burdens by state that allows for a separation of burdens into the share imposed on business.[10] The Census data are then used to allocate the combined business property tax payments between state and local governments based on their relative shares of total property tax revenue. The constructed local effective capital tax rate varies between 1.63 to 1.72 between 2000 and 2006 and is roughly three times the magnitude of the state capital tax rate.

State and local government size may have an important bearing on the tax-rate setting behavior of both states and localities. We include the relative size of a state, defined as the ratio of state-to-national population, to account for market-power potential. This is a crude version of a concentration index that is included for each state (rather than, say, the largest four states) since our focus is on how each individual state sets its capital tax rate. In the current context, larger states may enjoy agglomeration economies that can help mitigate the race-to-the-bottom in capital taxation and allow states to enjoy higher rates. Average locality size, defined as population relative to the actual number of local governments, controls for the choice options that capital confronts within a state. All else the same, larger local government size means fewer in-state options for firm locations. Rate increases on the part of large local governments will likely mean greater capital outflows from the state and the state may react by dampening rate increases to avoid base erosion and their ability to fund services.

We lag the tax rate variables in specifications that are consistent with the possibility of a one-year policy-response lag. Included as unique independent variables in the local equation are local debt per capita, local intergovernmental transfers (from the state and federal government)

[10] Ernst and Young graciously provided the data that were developed in a series of reports conducted over the past several years. See Cline, Fox, Neubig and Phillips (2005) for background. The authors calculate the business portion by subtracting the residential property tax component in the National Income and Products Accounts from the total property tax burden. This includes farm property in the business sector.

per capita, a dummy for the presence of a local sales tax and a dummy for the presence of a local personal income tax, with similar state-level controls included as unique independent variables in the state tax rate equation. The tax variables account for potential substitutability between business and other taxes. State and local debt may require higher business taxes to fund capital outlays. Grants from higher levels of government may support lower tax rates, or alternatively, capture lower tax capacity which may necessitate higher capital tax rates.

Variables used in the model are listed in Table 1 and summary statistics are provided in Table 2. A variety of common variables are included to control for characteristics of the population that may reflect public service demand, economic conditions, and political influences. Dummy variables account for whether the lower house of the state has a democratic majority and the governor is a democrat, with a similar variable if republicans dominate state government. Complementing these variables is a year dummy variable for whether there is a state house of representative's election or a gubernatorial election. The unemployment rate and per capita income are used to control for near-term and long-term economic conditions that might influence capital tax rate determination. We use the share of the population under 16 and the share of the population over 65 years of age to account for the potentially unique public service demands of different demographic groups.

6. Baseline Results

Our empirical analysis is conducted by first analyzing the vertical and horizontal interactions in a Nash setting, where each government sets its tax rates taking the other governments' tax rates as given.[11] Then, based on the results of indicative statistical tests, we

[11] We estimate the equations separately and as a system of equations because the error terms may be correlated. Results presented are those from separate equations but the results from the systems of equation estimates are similar in sign and magnitude to those presented here. The single equation estimates are presented because of the

estimate a model where states are assumed to be Stackelberg leaders, and local governments are followers. Following Hayashi and Boadway (2001), the Stackelberg procedure requires that the state utilizes information about the local government in setting its own tax rate. The basic structure in the Nash model is seen above in equations (4) and (5).

Table 3 reports our baseline results for the model where state and local capital taxes are estimated using pooled OLS with year fixed effects in a Nash environment.[12] Results are presented for all three weighting schemes described above. All tax rates are lagged in each equation to allow for possible policy lags and to reduce the potential for simultanetity bias. A separate set of estimates was prepared using contemporaneous values for policy instruments and instrumental variables. The coefficient estimates are very similar to those in Table 3, but the standard errors are generally larger.

Using all three weighting definitions, both state and local governments are found to have negative vertical reaction functions, indicating that state and local capital tax rates are strategic substitutes. In addition, estimates show that local governments respond more strongly to a state rate increase than state governments do to local increases – that is, local reaction functions are steeper than state reaction functions. Both results are consistent with some capital leaving the state as either level of government raises its capital tax rate, and the other level responds by lowering its rate to limit the degree of base decline. Local governments may respond more strongly (the steeper reaction function) because capital taxes are relatively more important in the local revenue structure, so maintaining the base is a higher priority. However, neither reaction is

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ability to provide multi-way clustered standard errors in this setting and because misspecification in one equation can negatively impact the system of equations.

[12] Estimates include time fixed effects but state fixed effects are not included as some of the state and local independent variables do not vary for an individual state over time.

sufficient to fully offset a rate increase by the other, so that the net effect would be higher state plus local capital taxation and presumably some loss of tax base.

State rates are positively related to the size of the state, suggesting that larger states have more market power in setting tax rates. One explanation is that capital is less mobile out of larger states so these states (or their constituent localities) can impose higher rates--effectively, large states are better able to enforce origin taxes and maintain their base. Capital may be less mobile out of larger states for a variety of reasons including: (1) tax-rate sensitive firms may in practice be better able to locate a low local tax rate option in response to an increase in the state rate or a rate increase by another in-state locality, (2) firms are more willing to pay the higher tax rate to ensure that they can exploit the larger market or can benefit from agglomeration effects, or (3) larger states have more location options with broad characteristics (e.g. variations in local labor market conditions) that firms are seeking.

Larger local governments reduce local tax rates. All else equal, large local governments mean fewer options inside the state, which increases the chance that local tax rate increases shift tax base out-of-state. Larger local governments mean that rate increases by one local government are likely to cause a greater outward flow of the base, both to other in-state local governments and to out-of-state jurisdictions, leading to an incentive to keep rates down to better compete for capital and ensure public service provision.

With the contiguity neighbor definitions, both home state and local tax rates have a positive reaction response to neighbor *state* rates, indicating that these rates are strategic complements with home state and local rates. No relationships are found between tax rates and inverse-distance weighted neighbor tax rates. Reaction functions, at least for commodity taxation, can conceptually take on any sign (Mintz and Tulkens, 1986), but a positive reaction

function is consistent with revenue maximization (Kanbur and Keen, 1993). Positive reaction functions are also consistent with a yardstick influence across state tax rates. Karkalakos and Kotsogiannis (2007) find positive horizontal reaction functions across Canadian provinces in their analysis of corporate tax rates. Our results indicate that home governments use the opportunity afforded by neighbor rate increases to raise their own rates, though the slopes of the reaction functions are less than one (each raises its own rate somewhat less than the neighbor's rate increase). Again, local government reaction functions are steeper than state reaction functions, suggesting that local governments are more aggressive in responding to the opportunities presented by higher neighbor rates. Reaction functions for neighbor's *local* rates are also positive, though the neighbor's local rate is not significant in the home state or local equations.

The presence of sales and personal income tax options generally lowers the extent to which local governments rely upon capital taxation as they substitute one revenue instrument for another. For states, on the other hand, only the sales tax diminishes reliance on state capital taxation. Both state and local governments lower the extent of capital taxation in light of higher unemployment rates, though the coefficient is only statistically significant for local governments in the inverse-distance contiguity case. This may evidence efforts by places with the least robust economy to keep effective capital tax rates low in an effort to attract more economic activity. State capital tax rates are also lower in higher income and Republican states. Higher levels of debt (statistically significant in only one case) and larger grants are associated with higher state capital tax rates.

7. Leaders and Followers

Our next step is an investigation of whether either state or local governments are Stackelberg leaders in the setting of effective capital tax rates. In models where governments are thought to be Stackelberg leaders, we would expect the leader government to use information about the follower to predict how the follower will respond to the leader's tax policy. We begin the investigation by estimating Granger causality tests for whether state rates Granger cause local rates and whether local rates Granger cause state rates. The estimation of Granger causality tests is summarized by the equations below:

$$T_{it} = \sum_{l=1}^{m} \alpha_l T_{it-l} + \sum_{l=1}^{k} \beta_l \tau_{it-l} + f_i + \lambda_t + \varepsilon_{it} \qquad (6)$$

$$\tau_{it} = \sum_{l=1}^{m} \delta_l T_{it-l} + \sum_{l=1}^{k} \gamma_l \tau_{it-l} + f_i + \lambda_t + \nu_{it}, \qquad (7)$$

where f are state-specific effects and λ are time-specific effects. OLS estimation of equations (6) and (7) is problematic because the correlation between the state-specific effects and the lagged dependent variables will cause estimates to be biased and inconsistent.[13] One common method to eliminate this problem entails taking the first difference of equations (6) and (7), which eliminates the state-specific variable. This leads to

$$\Delta T_{it} = \sum_{l=1}^{m} \alpha_l \Delta T_{it-l} + \sum_{l=1}^{k} \beta_l \Delta \tau_{it-l} + \Delta \varepsilon_{it} \qquad (8)$$

$$\Delta \tau_{it} = \sum_{l=1}^{m} \delta_l \Delta T_{it-l} + \sum_{l=1}^{k} \gamma_l \Delta \tau_{it-l} + \Delta \nu_{it}. \qquad (9)$$

Estimation of equations (8) and (9) remains a problem if the differenced error terms and differenced lagged dependent variables are correlated. In addition, standard Granger causality tests are parametric *F*-tests that rely on the assumption of normality, and have been criticized in the literature (Holmes and Hutton, 1992). Rather than impose the standard assumptions about

[13] See Holtz-Eakin et al., (1988) for a description of dynamic panel data models.

functional form and normality, we follow Holmes and Hutton (1990 and 1992) and employ the multiple-rank *F* test.[14] This process involves a monotonic transformation of the variables to eliminate problems associated with deviations of the error term from normality; however, the transformation will not eliminate any underlying causal relationship. Thus, we can make the strongest statement possible on causality, given available econometric tools.[15]

We perform the rank transformation and apply OLS to estimate

$$R(\Delta T_{it}) = \sum_{l=1}^{m} \alpha_l R(\Delta T_{it-l}) + \sum_{l=1}^{k} \beta_l R(\Delta \tau_{it-l}) + \sigma_{it} \qquad (10)$$

$$R(\Delta \tau_{it}) = \sum_{l=1}^{m} \delta_l R(\Delta T_{it-l}) + \sum_{l=1}^{k} \gamma_l R(\Delta \tau_{it-l}) + \mu_{it} \qquad (11)$$

where $R(\Delta T_{it})$ is defined as the rank transformation of ΔT_{it}. To conduct the Granger causality test, we test for joint significance of the coefficient estimates.[16] The local tax rate is said to Granger cause the state tax rate if the β from equation (10) are jointly significantly different from zero. A similar test is applied to determine whether state tax rates Granger cause local tax rates.

The *F*-tests of noncausality provide some evidence that state tax rates Granger cause local tax rates, but local tax rates do not Granger cause state tax rates. The results of the joint significance test indicate that the δ from equation (11) are jointly significant at the ten percent level but the β from equation (10) are not jointly significant. This is suggestive that states are Stackelberg leaders. Following Hayashi and Boadway (2001), the model was re-estimated to test

[14] Holmes and Hutton (1990 and 1992) describe the nonparametric analysis as better as long as one of the standard error assumptions such as normality, independence or homoscedasticity is violated.

[15] As Holmes and Hutton (1990) note, the multiple-rank *F* test speaks only to prima facie causality. In the current application there is strong economic support for some degree of causality from state tax rates to local tax rates and from local tax rates to state tax rates. However, even if the tests support causality, one cannot rule out other possible reasons for an econometric linkage between variables.

[16] Before estimation, optimal lag lengths were obtained using standard tests. In addition, the Levin-Lin-Chu panel unit root test was conducted on the dependent variables. All were found to be stationary in both level and first differenced form.

for evidence that states are Stackelberg leaders in the setting of capital tax rates by analyzing whether states consider the factors that go into the local government rate setting process when the state sets its rate. This is achieved by including the uniquely local control variables in the state equation, since states playing the Stackelberg game will set the rate in light of how they expect local governments to respond. Significant coefficients on the local variables are consistent with states acting as Stackelberg leaders. Because the state government may not accurately predict the local government's behavior or may not be able to fully adjust in a given period, the state may continue to respond to the local government's tax rate as the interaction is continuously repeated. For this purpose, we estimate the Stackelberg model with and without the local tax rate as a variable in the state tax rate equation.

Results for the Stackelberg models are presented in Tables 4 and 5 (with and without the local tax rate in the state equation, respectively). Note that new local equations are not estimated here since the empirical evidence is consistent with the local governments operating in a Nash environment. The Nash and Stackelberg reaction functions for states are qualitatively similar (see Tables 3 and 4).

The key difference between the results in structure across Table 4 and Table 3 above is that two local control variables in the state tax equation, local receipt of grants and the local sales tax, are individually significant. The coefficients suggest that states set their capital tax rates higher when they provide larger grants to local governments and lower when they anticipate that local governments will set higher sales tax rates. The local variables are not jointly significant in some versions of the state equations, though they are jointly significant if we assume a dynamic relationship and include contemporaneous and lagged local variables. The dynamic relationship is consistent with the Granger causality results and is also consistent with local governments

being followers. These results, along with the causality tests, provide support for the Stackelberg model being the preferred specification of the capital tax setting process. As shown in Table 4, the lagged local rate is independently significant in the state equation suggesting that states operate as leaders. The cross-state reaction functions are not statistically significant in Table 5, where states are assumed to have complete information on how their local governments behave.

While the Stackelberg model can be supported on the basis of the empirical evidence presented here, the results for the vertical reaction function do not differ appreciably from the Nash models presented in Table 3. Some of the relevant tax competition variables have consistent signs and levels of significance, and similar coefficient values. Exceptions are the neighbor state tax rate which is not significant in either equation. Neither the relative state size variable nor the state intergovernmental grants are statistically significant in the Stackleberg model.

Together the results point to a race to the bottom in capital taxation at the state level. These horizontal competition effects are reinforced by the positive reactions that neighbor state tax rates have on own-state local rates. Mitigating these downward pressures on capital tax rates are the vertical interactions within states for both the state and its local governments.

8. Conclusion

There is a large and growing literature that examines interactions in tax setting across and within government jurisdictions. As the literature has evolved, the scope of possible interactions has expanded as well, in reflection of the complex structure of governments. This paper explores some of these complexities by considering vertical and horizontal capital tax competition in a setting characterized by multiple federations. The analysis accommodates vertical competition within federations (states), horizontal competition across federations on the part of federations as

well as their constituent local governments, and competition between local governments in one state and other federations. We consider both Nash behavior on the part of all jurisdictions and Stackelberg behavior where states play the tax-setting game as leaders. Spatial econometric techniques are employed in the estimation using alternative definitions of the competing federation set.

The results reveal negative state and local capital tax reaction functions, a finding that is generally robust to alternative specifications of the model. The estimated local reaction functions are steeper than their state counterparts, perhaps a reflection of greater concerns over tax base flight and service delivery capacity. We also find that both home state and local tax rates react positively to neighbor state rates, a sign of strategic complementarity and evidence in support of a race to the bottom in capital taxation.

The analysis is extended to account for the possibility of Stackelberg behavior whereby state tax setting leads the setting of capital tax rates at the local level. Granger causality tests provide a smoking gun in favor of the Stackelberg model. Additional empirical tests provide further evidence in support of the Stackelberg model. Despite this alternative behavioral interpretation, the magnitude of coefficients for the relevant tax competition reaction functions is quite similar across model specifications as long as we allow for state governments having less than full information about local behavior.

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Table 1: Variable Definitions

Variable Name	Definition	Source
State Capital Tax	(State Government Tax Collections on Businesses from the Property Tax, Corporate Income Tax and Licences divided by State Income)*100	Census Bureau
Local Capital Tax	(Statewide Local Government Tax Collections on Businesses from the Property Tax divided by State Income)*100	Census Bureau
Neighbor's State Capital Tax	Average of State Capital Tax in bordering states	Authors' Calculations
Neighbors' Local Capital Tax	Average of Local Capital Tax in bordering states	Authors' Calculations
Average Locality Size	Population of state/number of local governments within the state	Census Bureau
Relative State Size	(State population/U.S. population)*100	Census Bureau
Local Sales Tax	Dummy equal to 1 if local governments in the state impose general sales taxes	Census Bureau
Local PIT	Dummy equal to 1 if local governments in the state impose personal income taxes	Census Bureau
Per Capita Income	Per capita income of the state	Bureau of Economic Analysis
Same Party = Democrat	Dummy variable equal to one if the lower house of the state government and the governor are Democrat	Authors' Calculations from U.S. Statistical Abstracts
Same Party = Republican	Dummy variable equal to one if the lower house of the state government and the governor are Republican	Authors' Calculations from U.S. Statistical Abstracts
Election Year Dummy	Dummy variable equal to one if it is an election year for either the lower house of the state government or the governor	Authors' Calculations from U.S. Statistical Abstracts
% of Pop 0-15	Percent of state population between ages 0 and 15	Census Bureau
% of Pop 65+	Percent of state population ages 65 and over	Census Bureau
Unemployment Rate	State Unemployment Rate	Bureau of Labor Statistics
Local Debt Per Capita	Statewide local government debt per capita	Census Bureau
Local Intergovernmental Transfers	Statewide local government per capita intergovernmental transfers from the state and federal governments	Census Bureau
State Sales Tax	Dummy equal to 1 if the state imposes a general sales tax	Census Bureau
State PIT	Dummy equal to 1 if the state imposes a personal income tax	Census Bureau
State Debt Per Capita	State per capita debt	Census Bureau
State Intergovernmental Transfers	State per capita intergovernmental transfers from the federal government	Census Bureau

Table 2: Summary Statistics

	2000		2006	
Variable	**Mean**	**Std. Dev**	**Mean**	**Std. Dev**
State Capital Tax	0.586	0.494	0.652	0.514
Local Capital Tax	1.623	0.585	1.696	0.657
Average Locality Size	12580.930	13912.970	13685.000	15964.260
Relative State Size	2.083	2.236	2.073	2.252
Local Sales Tax	0.667	0.476	0.708	0.459
Local PIT	0.271	0.449	0.271	0.449
Per Capita Income	28815.790	4461.102	36344.420	5385.987
Same Party = Democrat	0.146	0.357	0.250	0.438
Same Party = Republican	0.250	0.438	0.229	0.425
Election Year Dummy	0.229	0.425	0.708	0.459
% of Pop 0-15	22.685	1.428	21.414	1.648
% of Pop 65+	12.663	1.663	12.758	1.476
Unemployment Rate	3.785	0.865	4.410	0.959
Local Debt Per Capita	2648.523	1112.991	3531.211	1515.649
Local Intergovernmental Transfers	1114.580	292.925	1442.256	392.400
State Sales Tax	0.917	0.279	0.917	0.279
State PIT	0.875	0.334	0.875	0.334
State Debt Per Capita	2125.162	1313.623	3051.785	1791.666
State Intergovernmental Transfers	978.305	241.240	1505.265	505.703

Table 3: Lagged Vertical Tax Competition (Pooled OLS Models)

	Contiguity Matrix		Distance Contiguity Matrix		Inverse-Distance Contiguity Matrix	
Dependent Variable:	State Tax	Local Tax	State Tax	Local Tax	State Tax	Local Tax
Local Tax (t-1)	**-0.305*** **		**-0.279*** **		**-0.261*** **	
	(0.0957)		(0.0919)		(0.100)	
State Tax (t-1)		**-0.502*** **		**-0.516*** **		**-0.498*** **
		(0.124)		(0.119)		(0.112)
Neighbor's Local Tax (t-1)	0.0618	0.300	0.0474	0.299	0.793	-0.450
	(0.219)	(0.268)	(0.210)	(0.283)	(1.405)	(1.164)
Neighbor's State Tax (t-1)	**0.355** **	**0.805** **	0.235	0.382	0.575	0.746
	(0.159)	(0.397)	(0.152)	(0.372)	(1.040)	(1.162)
Average Locality Size	-0.00256	**-0.00983***	-0.00287	**-0.0107***	-0.00208	**-0.0150*** **
	(0.00273)	(0.00582)	(0.00286)	(0.00615)	(0.00327)	(0.00579)
Relative State Size	**0.0360** **	0.0573	**0.0363** **	0.0628	**0.0393*** **	0.0560
	(0.0163)	(0.0392)	(0.0161)	(0.0403)	(0.0152)	(0.0381)
Per Capita Income	**-0.0242** **	-0.0233	**-0.0225***	-0.0179	**-0.0236***	-0.0134
	(0.0121)	(0.0201)	(0.0128)	(0.0221)	(0.0139)	(0.0283)
Same Party = Democrat	-0.0972	-0.226*	-0.0745	-0.165	-0.0520	-0.143
	(0.0745)	(0.125)	(0.0738)	(0.153)	(0.0711)	(0.203)
Same Party = Republican	**-0.161*** **	0.0843	**-0.166*** **	0.0919	**-0.161*** **	0.125
	(0.0537)	(0.109)	(0.0494)	(0.107)	(0.0515)	(0.113)
Unemployment Rate (%)	-0.105	-0.101	-0.108	-0.115	-0.102	**-0.171***
	(0.0796)	(0.0833)	(0.0785)	(0.0877)	(0.0836)	(0.0980)
State Sales Tax Dummy	**-0.732** **		**-0.739** **		**-0.827*** **	
	(0.339)		(0.332)		(0.262)	
State Personal Income Tax Dummy	-0.0926		-0.0822		-0.0706	
	(0.0916)		(0.0891)		(0.0852)	
State Debt Per Capita	0.0689		**0.0765***		0.0505	
	(0.0436)		(0.0452)		(0.0683)	
State Intergovernmental Grants Per Capita	**0.192*** **		**0.180*** **		**0.204** **	

	(0.0675)		(0.0663)		(0.0978)	
Local Sales Tax Dummy		**-0.362****		**-0.446*****		**-0.511****
		(0.143)		(0.160)		(0.199)
Local Personal Income Tax Dummy		**-0.287****		**-0.237***		**-0.250***
		(0.137)		(0.132)		(0.139)
Local Debt Per Capita		0.00677		-0.00434		0.00102
		(0.0678)		(0.0685)		(0.0678)
Local Intergovernmental Grants Per Capita		0.0468		0.0464		0.161
		(0.294)		(0.291)		(0.248)
Constant	**2.323****	**2.454*****	**2.324*****	**2.659*****	0.941	**3.678****
	(0.941)	(0.721)	(0.898)	(0.769)	(2.974)	(1.796)
R-squared	0.497	0.370	0.491	0.327	0.480	0.302
Observations	288	288	288	288	288	288

Multi-way clustered standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 4: Lagged Stackelberg Vertical Tax Competition (Pooled OLS Models)

	Contiguity Matrix	Distance Contiguity Matrix	Inverse-Distance Contiguity Matrix
Dependent Variable:	State Tax	State Tax	State Tax
Local Tax (t-1)	**-0.291*** **	**-0.270*** **	**-0.260*** **
	(0.0813)	(0.0817)	(0.0899)
Neighbor's Local Tax (t-1)	-0.0353	-0.0233	0.738
	(0.226)	(0.219)	(1.209)
Neighbor's State Tax (t-1)	0.285	0.177	0.337
	(0.224)	(0.191)	(1.381)
Average Locality Size	-0.00496	-0.00501	-0.00333
	(0.00347)	(0.00363)	(0.00297)
Relative State Size	0.0287	0.0302	**0.0341***
	(0.0212)	(0.0201)	(0.0185)
Per Capita Income	**-0.0306** **	**-0.0288** **	**-0.0295** **
	(0.0121)	(0.0129)	(0.0146)
Same Party = Democrat	-0.0809	-0.0578	-0.0317
	(0.0929)	(0.0865)	(0.0751)
Same Party = Republican	**-0.137*** **	**-0.140*** **	**-0.132*** **
	(0.0471)	(0.0450)	(0.0419)
Unemployment Rate (%)	**-0.134***	**-0.133***	-0.121
	(0.0793)	(0.0761)	(0.0787)
State Sales Tax Dummy	**-0.648***	**-0.643***	**-0.696*** **
	(0.333)	(0.329)	(0.265)
State Personal Income Tax Dummy	-0.149	-0.144	-0.137
	(0.102)	(0.104)	(0.113)
State Debt Per Capita	0.0595	0.0638	0.0348
	(0.0507)	(0.0518)	(0.0745)
State Intergovernment Grants Per Capita	0.0634	0.0510	0.0866
	(0.0914)	(0.0930)	(0.0876)
Local Sales Tax Dummy	0.113	0.113	0.127
	(0.147)	(0.151)	(0.159)
Local Personal Income Tax Dummy	-0.0608	-0.0662	-0.0230
	(0.0690)	(0.0626)	(0.0694)
Local Debt Per Capita	0.179	0.171	0.110

	(0.115)	(0.107)	(0.120)
Local Intergovernment Grants Per Capita	**1.096***	**1.080***	**1.172***
	(0.620)	(0.611)	(0.651)
Local Sales Tax Dummy (t-1)	**-0.274***	**-0.281***	**-0.325***
	(0.150)	(0.156)	(0.171)
Local Personal Income Tax Dummy (t-1)	0.0447	0.0619	0.0765
	(0.118)	(0.113)	(0.109)
Local Debt Per Capita (t-1)	-0.197	-0.193	-0.126
	(0.129)	(0.127)	(0.138)
Local Intergovernment Grants Per Capita (t-1)	-0.840	-0.823	-0.961
	(0.607)	(0.592)	(0.601)
Constant	**2.767****	**2.725****	1.395
	(0.901)	(0.855)	(2.731)
R-squared	0.535	0.532	0.528
Observations	288	288	288
Chi-square Test of Joint Significance of Local Variables (excluding local tax rate)	**15.34***	**16.92****	**16.70****

Multi-way clustered standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5: Lagged Stackelberg Vertical Tax Competition without Lagged Local Tax Rate (Pooled OLS Models)

	Contiguity Matrix	Distance Contiguity Matrix	Inverse-Distance Contiguity Matrix
Dependent Variable:	State Tax	State Tax	State Tax
Neighbor's Local Tax (t-1)	-0.162	-0.144	0.820
	(0.251)	(0.247)	(1.304)
Neighbor's State Tax (t-1)	0.0411	0.0778	0.0195
	(0.238)	(0.199)	(1.521)
Average Locality Size	-0.00329	-0.00330	-0.000273
	(0.00302)	(0.00300)	(0.00258)
Relative State Size	0.0103	0.0119	0.0192
	(0.0216)	(0.0199)	(0.0187)
Per Capita Income	**-0.0259****	**-0.0253***	-0.0248
	(0.0125)	(0.0130)	(0.0161)
Same Party = Democrat	-0.00551	-0.00359	0.0153
	(0.0959)	(0.0912)	(0.0781)
Same Party = Republican	**-0.151*****	**-0.155*****	**-0.155*****
	(0.0504)	(0.0499)	(0.0434)
Unemployment Rate (%)	-0.120	-0.116	-0.0826
	(0.0800)	(0.0773)	(0.0730)
State Sales Tax Dummy	**-0.741****	**-0.742****	**-0.781*****
	(0.359)	(0.355)	(0.285)
State Personal Income Tax Dummy	-0.0503	-0.0496	-0.0394
	(0.0966)	(0.100)	(0.117)
State Debt Per Capita	0.0693	0.0722	0.0333
	(0.0584)	(0.0592)	(0.0813)
State Intergovernment Grants Per Capita	-0.0670	-0.0697	-0.0171
	(0.112)	(0.113)	(0.0987)
Local Sales Tax Dummy	0.202	0.202	0.226
	(0.221)	(0.217)	(0.218)
Local Personal Income Tax Dummy	-0.0248	-0.0413	0.0162
	(0.0899)	(0.0876)	(0.102)
Local Debt Per Capita	0.0331	0.0368	-0.0367
	(0.0746)	(0.0738)	(0.0819)
Local Intergovernment Grants Per Capita	**1.288***	**1.236***	**1.289***

	(0.723)	(0.695)	(0.749)
Local Sales Tax Dummy (t-1)	-0.243	-0.230	-0.286
	(0.210)	(0.290)	(0.205)
Local Personal Income Tax Dummy (t-1)	0.108	0.110	0.118
	(0.136)	(0.137)	(0.144)
Local Debt Per Capita (t-1)	-0.0639	-0.0692	0.00894
	(0.0963)	(0.103)	(0.102)
Local Intergovernment Grants Per Capita (t-1)	-0.908	-0.862	-1.020
	(0.679)	(0.658)	(0.679)
Constant	**2.352*** **	**2.275*** **	0.689
	(0.871)	(0.813)	(2.840)
R-squared	0.453	0.455	0.453
Observations	288	288	288
Chi-square Test of Joint Significance of Local Variables	**23.55*** **	**24.69*** **	**18.37** **

Multi-way clustered standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1