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Tax Competition Among U.S. States: Racing to the Bottom or Riding on a Seesaw?

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Abstract

Dramatic declines in capital tax rates among U.S. states and European countries have been linked by many commentators to tax competition, an inevitable “race to the bottom,” and underprovision of local public goods. This paper analyzes the reaction of capital tax policy in a given U.S. state to changes in capital tax policy by other states. Our study is undertaken with a novel panel data set covering the 48 contiguous U.S. states for the period 1965 to 2006 and is guided by the theory of strategic tax competition. The latter suggests that capital tax policy is a function of “foreign” (out-of-state) tax policy, preferences for government services, home state and foreign state economic and demographic conditions. The slope of the reaction function–the equilibrium response of home state to foreign state tax policy–is *negative*, contrary to casual evidence and many prior empirical studies of fiscal reaction functions. This result, which stands in contrast to most published findings, is due to two critical elements–allowing for delayed responses to foreign tax changes and for heterogeneous responses to aggregate shocks. Omitting either of these elements leads to a misspecified model and a positively sloped reaction function. Our results suggest that the secular decline in capital tax rates, at least among U.S. states, reflects synchronous responses among states to common shocks rather than competitive responses to foreign state tax policy. While striking given prior empirical findings, these results are fully consistent with the qualitative and quantitative implications of the theoretical model developed in this paper and presented elsewhere in the literature. Rather than “racing to the bottom,” our findings suggest that states are “riding on a seesaw.” Consequently, tax competition may lead to an increase in the provision of local public goods, and policies aimed at restricting tax competition to stem the tide of declining capital taxation are likely to be ineffective.

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Keywords: tax competition, state taxation, reaction functions, capital taxation.

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> Wisconsin is open for business. In these challenging economic times while Illinois is raising taxes, we are lowering them.
>
> Governor Scott Walker of Wisconsin (January 12, 2011)

I. Introduction

This paper provides an empirical analysis of an important element in the theory of strategic tax competition, the reaction of capital tax policy in a given jurisdiction to changes in capital tax policy by neighboring jurisdictions. The analysis is motivated in part by the dramatic decline among industrialized countries in capital tax rates over the past few decades. There has been much debate over what factors are causing this decline and, in particular, how much of it is due to competition among jurisdictions. A number of cross-country empirical studies have attempted to identify the causes, but this research faces challenges from the substantial heterogeneity across countries in institutions, regulations, and business environments that weigh heavily on tax policy and impede capital flows. U.S. states provide an ideal laboratory for investigating the determination of capital tax rates and the role of tax competition because, while states have much latitude for setting their own capital tax policies and do, in fact, set widely varying tax policies, they share many important institutional and environmental factors in common. Moreover, the general downward trend in capital taxation observed among industrialized countries in recent decades has also been observed among U.S. states.

This trend among states can be seen in Figures 1 through 4, which show national averages of the major state capital tax policies from 1969 to 2006. In 1968, no state had an investment tax credit (ITC). Since then, as shown in Figure 1, ITC adoptions have grown steadily; by 2006, 24 states have or have had an ITC, and the average rate among states with an ITC has risen considerably to over 4%. Figure 2 displays the average ITC and corporate income tax (CIT) rates over all states. The national average ITC rate has increased in a nearly monotonic fashion and reaches nearly 2.0% by the end of the period. While the average CIT rate increased from the beginning of the period until 1991, it has fallen moderately since then. The impact of these two tax variables on the incentive to acquire capital can be measured by the tax wedge on capital (TWC), which is the tax component of the user cost of capital.[1] Figure 3 documents that the average TWC has fallen markedly in recent years. This pattern is confirmed by two additional tax series displayed in Figure 4. The capital apportionment weight (CAW) is the weight on capital in a state's formula for apportioning national corporate income to the state; similar to a lower CIT rate, a lower CAW may provide an incentive to locate capital in the state. The average CAW series has fallen sharply, declining by approximately 10 percentage points. An alternative perspective on capital tax policy is provided by the average corporate tax (ACT) rate, defined as the ratio of corporate tax revenues to corporate income. As shown in Figure 4, the average ACT peaked in 1980. Since then, this procyclical series has drifted downward. Viewed from a variety of perspectives, state capital taxation has changed greatly in recent years and has become more "business friendly." These aggregate movements, buttressed with anecdotal observations and past empirical studies, suggest to many observers that states are engaged in a "race to the bottom."

The empirical results in this paper challenge that conclusion. We find that the slope of the reaction function – the equilibrium response of home state tax policy to foreign state tax policy – is *negative*. This result – reflected in the quotation above from the Governor of Wisconsin – runs contrary to the casual empirical evidence in Figures 1 through 4, the findings in many prior empirical results, and the implications of some theoretical models. We document that this seeming paradox is due to two critical elements omitted in most prior empirical studies. First, aggregate shocks affecting all states create common incentives that lead states to act synchronously. Absent proper conditioning for aggregate shocks, a positively sloped reaction function is obtained with our data. Second, in theory, tax competition is driven by capital mobility among states, but the flow of capital is not instantaneous, instead occurring over several years. A properly specified model needs to allow for lagged responses. In our data, static models also generate a positively sloped reaction function. When we condition on aggregate shocks <u>and</u> allow for delayed responses, we find that the tax reaction function is negatively sloped.

While this empirical result is striking, it is not surprising and is fully consistent with the qualitative and quantitative implications of the theoretical model developed in this paper. Our findings suggest that the dramatic declines in state capital taxation in recent decades are not driven by tax competition among states, but rather from aggregate shocks such as changes in tax rates and input costs abroad, U.S. macroeconomic conditions, the capital income share, and

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[1] The *TWC* series equals $\{[(1-ITC-CIT\cdot TD)/(1-CIT)]-1.0\}$, where *TD* is the present value of tax depreciation allowances and ITC and CIT reflect only state taxes. See Appendix C for details.

technology. These factors impact all states simultaneously, though their importance may vary by state. Rather than states "racing to the bottom" (a competitive response of tax rates in the same direction), our results suggest that state tax competition is better characterized by states "riding on a seesaw" (a competitive response in the opposite direction).

Whether states are "racing to the bottom" or "riding on a seesaw" is important in current policy debates, both in the U.S. and abroad. Many analysts and policymakers point to the secular decline in marginal and average capital tax rates (documented in Figures 1 to 4) as "proof" that states are engaged in a harmful race to the bottom necessitating federal legislation or judicial action. For instance, a 2006 Supreme Court case, *Cuno v. DaimlerChrysler*, centered on whether state investment tax credits are a form of harmful tax competition and could run afoul of the Commerce Clause of the U.S. Constitution.[2] In recent years, the U.S. Congress has considered several bills that would alter states' capacity to set various capital tax policies independently. The severe budget strains on many state governments during the Great Recession and its aftermath further heightened concerns that interstate tax competition was "forcing" states to forego badly needed tax revenues at a time when spending on automatic stabilizer programs was rising and personal tax revenues were falling.[3]

State business taxes and their implications for tax competition are also relevant for current policy debates in Europe.[4] As mentioned above, corporate tax rates among OECD countries also have declined sharply over the past two or three decades (Devereux, Rodoano, and Lockwood, 2008, Figure 1; U.S. Treasury, 2007, Chart 5.1; Keen and Konrad, 2013, Figure 1). This decline has led to deliberations among European Union (EU) officials over whether to impose tax harmonization measures (McLure, 2008). As intra-union capital mobility rises toward levels approaching that among U.S. states, the U.S. experience may help inform the EU debate. Our results based on U.S. states suggest that policies aimed at restricting tax competition as a means of stemming the tide of declining capital taxation are likely to be ineffective. If aggregate

[2] The U.S. Commerce Clause states that "The Congress shall have Power … To regulate Commerce with foreign Nations, and among the several States, and with the Indian tribes; …" (United States Constitution, 1787, article I, section 8). See Enrich (2007) and Stark and Wilson (2006) for discussions of the Commerce Clause and its relation to tax policy.

[3] The cost of state and local business tax incentives and their importance for business location decisions was the subject of a series of articles in the *New York Times* (Story, 2012).

[4] The restrictions in the U.S. Commerce Clause are echoed in the Treaty of Rome section on *Aids Granted by States*: "Save as otherwise provided in this Treaty, any aid granted by a Member State or through State resources in any form whatsoever which distorts or threatens to distort competition by favouring certain undertakings or the production of certain goods shall, in so far as it affects trade between Member States, be incompatible with the common market" (Article 87).

shocks, not tax competition, are driving the secular movements in capital taxation, the elimination of tax competition will do little to stop or reverse these trends.

Our paper proceeds as follows. Section II develops a theoretical two-region model of capital taxation that emphasizes the critical roles played by the relative preference of residents for public vs. private goods and Wagner's Law.[5] We show that the sign of the slope of the reaction function of home state to foreign state tax policy depends on the income elasticity of public goods relative to private goods. To develop intuition for this important result, consider the case when the capital tax rate for a neighboring state rises. In turn, mobile capital (eventually) flows into the home state and its tax base rises. If the income elasticity of public goods relative to private goods is negative, then residents will prefer to use this income "windfall" to finance a tax cut – a negative or "see-saw" tax reaction – that results in lower public good consumption relative to private good consumption. Alternatively, if the income elasticity of public goods relative to private goods is positive, then residents will prefer to use the "windfall" to disproportionately increase public good consumption, necessitating a higher capital tax rate – a positive or "race to the bottom" tax reaction. Thus, the slope of the reaction function depends on whether private goods are necessities or luxuries, a condition closely related to the validity of Wagner's Law. Apart from the ambiguity of the sign of the slope, the theoretical model has an additional and novel implication that the absolute value of the slope increases with the mobility of capital. Tax instruments that target new, highly-mobile capital (the ITC) should have larger reaction function slopes than instruments targeting old, less mobile capital (the CIT).

Section III discusses our panel dataset for the 48 contiguous U.S. states for the period 1965 to 2006. This dataset has the virtues of a substantial amount of cross-section and time-series variation for an economic environment relatively free of impediments to the flow of capital. We have data on five tax variables – the investment tax credit, the corporate income tax rate, the tax wedge on capital, the average corporate tax rate, and the capital apportionment weight – and political, demographic, and economic variables serving as controls and instruments.

Section IV presents the estimating equation that allows for time lags of the spatially lagged tax variable and heterogeneous responses to aggregate shocks. Time lags reflect that tax policy responses by states are not instantaneous because of adjustment frictions and/or dynamic strategic interactions. The former occurs because of factor adjustment costs (Wildasin, 2003); the latter if tax competition is played as a dynamic game (e.g., the Stackelberg leader game analyzed

[5] Wagner's Law states that the share of government spending (as a percentage of GDP) increases with aggregate income. It is named after the 19th century German economist, Adolph Wagner.

by Altshuler and Goodspeed, 2015). We go beyond the standard time fixed effects estimator that constrains responses to an aggregate shock to be homogeneous across states. Instead, we employ the Common Correlated Effects (CCE) estimator (Pesaran, 2006) that permits heterogeneous responses across states. Additionally, the theory of tax competition strongly implies that there will be an endogeneity problem with estimating the slope of the reaction function. This estimation problem is addressed with a novel procedure that selects valid instruments based on their relevance from over 1,000 candidate instrument sets. Section V presents our empirical results that document the importance of accounting for delayed responses and aggregate shocks. When controls for these elements are excluded, we obtain a positively sloped reaction function, as reported in most prior work. By contrast, when the econometric model allows for both time lags of the spatially lagged tax variable and heterogeneous responses to aggregate shocks, the reaction function has a negative slope. These results are robust in several dimensions, including measuring capital income taxation by the tax wedge on capital or the capital apportionment weight. However, the theoretical prediction from our model that the slope is larger (in absolute value) for the ITC relative to the CIT receives mixed support across a variety of models.

Section VI offers a brief discussion of some of the relevant empirical literature on reaction functions.

Section VII summarizes how our "riding on a seesaw" finding informs policy discussions concerning tax competition and capital mobility.

II. The Tax Reaction Function: Theoretical Underpinnings And Empirical Implications

A. A Perspective on the Theoretical Literature

A stark tension exists in the tax competition literature. On the one hand, the casual evidence (e.g., Figures 1 to 4) and formal econometric results have led to a broad consensus of a positively sloped reaction function and a race to the bottom. In contrast to this consensus, theoretical models imply that the slope of the reaction function is uncertain. The theoretical possibility of a negatively sloped reaction function has been established, though not usually highlighted in, for example, Mintz and Tulkens (1986, Section 3.2 and fn. 15), Wilson and Janeba (2005, p. 1218), and Zodrow and Mieszkowski (1986, Section III).[6] A negatively sloped

[6] See Keen and Konrad (2013) for a recent survey. Some models of tax competition yield only a positively sloped reaction function, but the vast majority of those models assume revenue maximization (Kanbur and Keen, 1993).

reaction function has received more attention in Mendoza and Tesar (2005), who establish that, when government spending is held constant, the occurrence of a race to the bottom is sensitive to which tax instrument (labor vs. consumption tax rates) is used to balance the budget in the face of a decrease in the capital income tax rate. Wildasin (1988) makes the case that if governments optimize over expenditures (and tax rates adjust residually), the slope of the reaction function can be negative. In recent contributions, Razin and Sadka (2011), Vrijburg and de Mooij (2016), and Wildasin (2014) show, respectively, that a negatively sloped reaction function can occur when there is an upwardly sloping supply of immigrants, the substitutability of public and private goods (in a direct utility function) is sufficiently low, or public good consumption is sufficiently inelastic.

This section takes a different approach to modeling strategic competition. Since the main channel of influence of capital taxes is through the mobility of capital and subsequent income "windfall," it is natural to model household preferences in terms of an indirect utility function. In our framework, the slope of the reaction function can be positive ("racing to the bottom") or negative ("riding on a seesaw"). This slope depends on the sign of one key parameter – the income elasticity of public goods relative to private goods. The sign of this elasticity is related to whether private goods are necessities or luxuries, a condition closely related to the validity of Wagner's Law. Our model is based on a utility function that is more general than the Cobb-Douglas or CES direct utility functions (demonstrated in Appendix B.3) and generates a novel implication relating the sensitivity of the reaction function slope to capital mobility.

B. A Model Of Tax Competition

The central variables in our model of tax competition are the home state (τ) and foreign state (τ^f) business capital tax rates and the ratio of public goods to private goods consumption ($\zeta \equiv g / c$). The supply side of the model relates this relative public good consumption to the home state capital tax rate. Demand follows from an indirect utility function. The government chooses business capital tax policy to maximize the utility of the representative domestic household. Adopting the standard Nash assumption used in the literature, we assume policymakers in the home state treat foreign tax policy as given. A detailed derivation of this model is presented in Appendix A, and some important analytic details in Appendix B. The broad contours of our model are presented in this sub-section.

The supply of the relative public good is based on five relations. First, production in the home state is determined by a Cobb-Douglas function (adopted for analytic convenience) that depends on a mobile capital stock and a fixed factor of production, such as land or infrastructure.

The capital stock available for home production is the sum of the capital stock owned by home residents and, given the mobility of capital, the capital stock owned by foreign residents but located in the home state. Second, as a result of capital mobility, the capital stock in a given state is sensitive to capital income tax rates prevailing in home and foreign states. Third, net income is linked to expenditures by means of GDP accounting relations. Net income available for domestic expenditures is measured by gross income (production) less the return on capital assets owned by foreign residents but located in the home state; domestic expenditures are the sum of the consumption of public and private goods. Fourth, the government budget constraint equates public goods expenditure to two sources of tax revenue, an origin-based tax on capital income and a sales tax. Fifth, capital imported from abroad earns the same return as domestic capital. When these relations are combined, relative public good consumption is positively related to the home tax rate. This relation is presented in Figure 5; note that the upward sloping "supply" curve is the same in panels A, B, and C. As the home tax rate increases, more resources are devoted to the public sector, and the supply of the relative public good rises.

The demand side of the model is based on a utility function that represents preferences for public and private goods and that policymakers maximize by their choice of τ.[7] We represent the utility of the representative home resident by the addilog utility function. Houthakker (1960) introduced this function and noted that it is most suitable when the arguments in the utility function are large distinct aggregates and when the primary force driving allocations is through changes in income. Both properties are satisfied in our tax competition setting, and we work with the following indirect utility function ($V[y]$),

$$V[y] = \xi_g \left(y / p_g \right)^{\theta_g} + \xi_c \left(y / p_c \right)^{\theta_c}, \tag{1}$$

where $\theta_c, \theta_g, \xi_c$, and ξ_g are positive parameters representing preferences, p_c and p_g are the prices for c and g, respectively, and y is income (or production less payments to foreign capital). A key property of the addilog indirect utility function is that the "ratios between any two expenditures have a constant elasticity with respect to total expenditure" (Houthakker, 1960, p.

[7] In the tax competition literature, the standard approach for representing preferences involves a direct utility function with c and g as arguments. This approach can be followed in our model to determine the optimal τ (τ^*). A specific example is provided in Appendix B.4 and, while it yields an explicit solution for τ^*, this solution is not fully informative for the purposes of this study. Instead, we work with an indirect utility function corresponding to the direct utility function in terms of c and g. Sufficient conditions linking primal and dual representations are positive prices, local non-satiation in c and g, and strictly convex preferences; these conditions also ensure uniqueness (Kreps, 1990, Propositions 2.13 and 2.14, pp. 45-48).

253). Relying on Roy's identity to generate the demand functions for g and c, we obtain after some additional manipulation the following equation for the ratio of the demands for g to c (Houthakker, 1960, equation (30)), which we refer to as the relative demand for public goods,

$$\zeta \equiv g/c = \xi \, p \, y^{\eta_{\zeta,y}}, \tag{2a}$$

$$\xi \equiv \left(\xi_g \theta_g / \xi_c \theta_c\right) > 0, \tag{2b}$$

$$p \equiv \left(p_c^{(\theta_c+1)} / p_g^{(\theta_g+1)}\right) > 0, \tag{2c}$$

$$\eta_{\zeta,y} \equiv \theta_g - \theta_c >=< 0. \tag{2d}$$

A preference between public and private goods is a key element in our framework, as well as several other tax competition models. In equation (2), this preference is represented by the θ_g and θ_c parameters whose difference defines the income elasticity of public goods relative to private goods, $\eta_{\zeta,y}$. Since income is negatively related to τ (as an increase in the home country tax rate results in a movement of capital out of the home country and a decrease in income), the slope of the demand curve in (ζ, τ) space will be opposite that of the sign of $\eta_{\zeta,y}$. As shown in Figure 5, there are three cases to consider depending on whether $\eta_{\zeta,y}$ is zero, positive, or negative. The intersection of the demand and supply curves determines the equilibrium home capital tax rate, τ^*.

These schedules also determine the slope of the reaction function, $d\tau^*/d\tau^f$. While the demand and supply functions depend on several parameters, the most important for our study are τ^f and $\eta_{\zeta,y}$. To develop intuition for the interaction between the slope of the reaction function and alternative values of $\eta_{\zeta,y}$, consider the situation where the foreign capital tax rate rises. Mobile capital (eventually) flows into the home state, increasing the tax base.[8] The allocation of this "windfall" income to public and private goods may shift the demand curve. This shift and the subsequent impact on financing public goods through taxation are the key elements determining the slope of the reaction function. The supply curve does not shift, owing to the constancy of factor shares following from the Cobb-Douglas production function.

Shifts in the demand curve are shown by the dashed lines in Figure 5. The corresponding

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[8] An additional benefit from the relatively lower tax rate (not modeled here) is that, if firms in the home state are non-competitive, the capital inflow increases production and competitive pressures, possibly lowers non-competitive profit margins, and increases welfare. This channel has been documented in the context of offshore financial centers by Rose and Spiegel (2007).

changes in the equilibrium τ^*'s represent the slopes of the reaction function, and there are three cases to consider depending on whether $\eta_{\zeta,y}$ is zero, positive, or negative. Case I assumes that the proportion of resources devoted to public and private goods remains unaltered ($\eta_{\zeta,y} = 0$). Per equation (2a), the demand curve does not shift, the equilibrium home capital tax rate does not change, and the slope of the reaction function is zero. Thus, the windfall does not result in a change in the home tax rate or an alteration in relative public good consumption.

Case II assumes a preference for diverting a disproportionate amount of the windfall toward the public good ($\eta_{\zeta,y} > 0$). In this case, the windfall leads to a rightward shift in the demand curve. Since public goods need to be financed by tax revenues, τ^* increases and the reaction function is positively sloped.

Case III assumes a preference for diverting a disproportionate amount of the windfall away from the public good ($\eta_{\zeta,y} < 0$). For instance, residents may view current levels of public services as satisfactory and would rather spend most of the windfall on private consumption. The demand curve thus shifts leftward. Thus, the windfall decreases the home capital tax rate and relative public good consumption, and it results in a negatively sloped or "see-saw" reaction function.

The above analysis highlights that the slope of the reaction function is indeterminate *a priori* and depends crucially on the income elasticity of public goods relative to private goods. The appropriate value for $\eta_{\zeta,y}$ is closely related to the validity of Wagner's Law. Unfortunately, the empirical literature has reached different conclusions, with the time series evidence tending to favor the Law ($\eta_{\zeta,y} > 0$), while cross-section evidence finds that $\eta_{\zeta,y} < 0$ (Ram, 1987).

C. Two Empirical Implications

Complementary to the graphical analysis, our model generates a specific equation relating home and foreign capital tax rates that proves useful in generating an additional empirical implication. Differentiating this equation (equation (A-9) in Appendix A) with respect to τ^* and τ^f with the chain rule and rearranging yields the following reaction function,

$$\frac{d\tau^*}{d\tau^f} = \frac{\eta_{\zeta,y}\,\Gamma}{\left(\eta_{\zeta,y}\Gamma + \left((\tau\,\pi)\,/\,(\zeta(1-\tau\,\pi - s)^2)\right)\right)}, \tag{3a}$$

$$\Gamma \equiv \eta_{y,K} \cdot (-\eta_{K,\tau}) \geq 0, \tag{3b}$$

where τ is the capital income tax rate, π is capital income, s is the sales tax rate, the η's are elasticities, and $\eta_{y,K}$ and $-\eta_{K,\tau}$ are positive. The product of these latter two parameters is represented by Γ, defined in equation (3b), and interpreted as the change in output from a tax-induced flow of capital. The three cases considered in Section II.B and Figure 5 follow straightaway when the value of $\eta_{\zeta,y}$ is zero, positive, or negative.[9]

A second empirical prediction from our model about the reaction function is that the slope should vary systematically depending on whether the tax instrument applies to highly mobile new capital or less mobile old capital.[10] Capital mobility is measured by the absolute value of the elasticity of capital with respect to the tax instrument, $-\eta_{K,\tau}$. Differentiating equation (3a) with respect to this elasticity, we obtain the following result,

$$\frac{d\left(d\tau^* \big/ d\tau^f \right)}{d(-\eta_{k,\tau})} = \left(\frac{\eta_{\zeta,y} * \eta_{y,K} * \left((\tau\pi)/(\zeta(\tau\pi + s)^2 \right)}{\left(\eta_{\zeta,y} * \Gamma + \left((\tau\pi)/(\zeta(\tau\pi+s)^2) \right) \right)^2} \right) \begin{pmatrix} = 0 & \text{if} & \eta_{\zeta,y} = 0 \\ > 0 & \text{if} & \eta_{\zeta,y} > 0 \\ < 0 & \text{if} & \eta_{\zeta,y} < 0 \end{pmatrix}. \tag{4}$$

This equation shows that the magnitude of the reaction function slope is affected by the interaction between capital mobility ($-\eta_{K,\tau} > 0$) and $\eta_{\zeta,y}$. If $\eta_{\zeta,y} < 0$ ($\eta_{\zeta,y} > 0$), the slope of the reaction function will be negative (positive), and an increase in capital mobility will make the reaction function slope even more negative (positive). Intuitively, the more responsive capital is to tax stimuli (i.e., the higher is $-\eta_{K,\tau}$), the larger the movements in the tax base resulting from home vs. foreign tax differential changes, and hence the greater the responsiveness of the home tax rate to changes in the foreign tax rate. These scenarios imply that a negatively sloped (positively sloped) reaction function will be more negative (more positive) for the tax instrument targeting relatively mobile capital. In the empirical work, we expect that the slope of the reaction function will be greater in absolute value for the investment tax credit affecting new capital versus the corporate income tax rate that affects both new and old capital,

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[9] Signing the third case requires an additional condition, $0 > \eta_{\zeta,y} > -3$. This sufficient condition is based on the following calibration. The two elasticities defining Γ ($-\eta_{K,\tau}$ and $\eta_{y,K}$) are 1.00 and 0.33 (capital's share in production), respectively. The sum $(\tau\pi + s)$ is defined in terms of the theoretical model's government budget constraint (equations (A-5) and (A-7)) and is related to the ratio of public to private consumption, $(\tau\pi + s) = \zeta/(1+\zeta)$. The ζ and s parameters are estimated from NIPA data (Tables 1.1.5 and 3.20) as averages for the period 2000-2009: $\zeta = 0.270$, $s = 0.025$, and hence $\tau\pi = 0.188$. If $0 > \eta_{\zeta,y} > -3$, then $(\eta_{\zeta,y} * \Gamma) > -1$ and, since $(\tau\pi)/(\zeta(1-\tau\pi-s)^2 > 1$, the denominator of equation (4) is positive, and the overall derivative negative for the third case where $\eta_{\zeta,y} < 0$.

[10] Wildasin (2007) makes an important point about the differential sensitivity of "new" and "old" capital to the ITC and CIT, respectively, and discusses the implications for tax policy and rent transfers.

$$\left|\frac{d\,ITC}{d\,ITC^{f}}\right| > \left|\frac{d\,CIT}{d\,CIT^{f}}\right| \,. \tag{5}$$

III. U.S. State-Level Panel Data

Our estimates of the capital-tax reaction function are based on a U.S. state-level panel data for the period 1965 to 2011, though the sample period for our baseline results ends at 2006 to avoid the possibly distorting effects of the financial crisis and the Great Recession. The panel aspect of these data is crucial for understanding state tax policy for at least three reasons. First, state-specific fixed factors, such as natural amenities and industry mix, affect a state's desire for government services and hence its tax and expenditure policies. Initial policies, stemming perhaps from historical policy choices persisting to the present era due to political economy forces (Coate and Morris, 1999), also determine current policies. The impact of these and other state-specific fixed factors are accounted for with state fixed effects. Second, state tax policy may be sensitive to aggregate shocks (e.g., energy prices) that vary over time, and these influences will be captured by time fixed effects or, more generally, by the CCE estimator that allows heterogeneous responses across states. Third, panel data long in the time dimension allow for the possibility that the response of state tax policy is distributed over several years. As we shall see in Section V, the latter two factors prove very important in the empirical analysis. We now turn to a discussion of the data underlying the variables used in our empirical analysis. Details about variable definitions and data sources are provided in Appendix C.

A. Capital Tax Policy

The model developed above, as well as the tax competition literature in general, analyzes the determination of a single tax on each unit of capital. Across the 48 states, the primary capital-tax policies are investment tax credits (ITC) and the corporate income tax (CIT). These policies target different types of capital, and hence their reaction functions should have different slopes that depend on the degree of mobility of the targeted capital. The reaction functions associated with these two tax variables form our baseline empirical results presented in Section V.A. Robustness is explored in Section V.B, V.C, and V.D. We extend our analysis by estimating the reaction functions associated with three other tax variables – the tax wedge on capital, the average corporate tax rate, and the capital apportionment weight – in Section V.E. Before presenting those results, we discuss the data in this section and then some estimation issues in Section IV.

B. Control Variables

Variation in state capital tax policy is due, in part, to variation in demographic, economic, and political preference control variables that we measure by population (POPULATION), one-year lagged real state GDP growth (GDPGROWTH), and voter preferences (PREFERENCES), respectively. State population data come from the U.S. Census Bureau and state GDP data come from the Bureau of Economic Analysis.

Political preferences of state residents, while unobserved, should to a large extent be revealed by electoral outcomes. Specifically, we measure the following two political outcomes as indicator variables:

(a) the governor is Republican. (The complementary class of politicians is Democrat or Independent. An informal examination of the political landscape suggests that Independents tend to be more closely aligned with the Democratic Party. We thus treat Democrats and Independents as belonging to the same class);

(b) the majority of both houses of the legislature are Republican.

Based on these two outcomes, the PREFERENCES variable takes on one of three values:

0 if the governor and the majority of both houses of the legislature are not Republican;

1/2 if the governor is Republican but the majority of both houses of the legislature are not Republican, or if the governor is not Republican but the majority of both houses of the legislature are Republican;

1 if the governor and the majority of both houses of the legislature are Republican.

C. Foreign (Out-of-State) Variables

The two-state model developed in Section II is useful for understanding the intuition of strategic tax competition, but its focus on a single foreign jurisdiction is obviously highly stylized. In taking a tax competition model to data, one must confront the issue of evaluating the model when there are many foreign states competing for the capital tax base. It is generally infeasible to allow for a separate slope of the tax reaction function for each foreign state. The approach taken in the literature, which we follow in this paper, is to measure foreign state variables (denoted by a superscript *f*) using spatial lags of the home state variable. A spatial lag is a weighted average of any $x_{i,t}$ variable over all foreign states,

$$x_{i,t}^{f} \equiv S^{1}\left\{x_{i,t}\right\} = \sum_{j \neq i}^{J} \omega_{i,j}\, x_{j,t}\,, \tag{6a}$$

$$\sum_{j \neq i}^{J} \omega_{i,j} = 1\,, \tag{6b}$$

where $S^{p}\{.\}$ is the spatial lag operator of order p and $\omega_{i,j}$ is a weight defining the "relatedness" of state i to the remaining $J-1$ states indexed by j. The constraint in equation (6b) normalizes the weights to sum to one for a given i^{th} state. In this paper, we focus on tax competition among the 48 contiguous U.S. states.[11]

The elements of the weighting matrix are chosen *a priori* . The most natural weighting scheme and the one used most frequently in the literature is based on geographic proximity. We construct the $\omega_{i,j}$'s with elements equal to the inverse-distance between state pairs, where distance is the number of miles between each state's population centroid. A shortcoming of this geographic proximity measure is that it may not sufficiently discriminate among states. For example, while one might suspect that the economic interactions between California and Texas are greater than between California and Nebraska, the geographic proximity measure will give approximately equal weight to both pairs of states. Thus, in Section V.C we consider the robustness of our baseline results to using either of two alternative spatial weighting matrices, one based on commodity trade-flows between states and another based on inverse-distance multiplied by population.

D. Candidate Instruments

We rely on eight voter preference variables defined over foreign states to form the candidate sets of instruments; these instruments are discussed in detail in Section IV.C. In addition to the two preference variables listed above in Section III.B for the governorship (a) and legislature (b), we consider the following six political variables:

(c) the majority of both houses of the legislature are Democrats or Independents;

(d) the governorship changed last year from a Republican to a Democrat;

(e) the majority control of the legislature changed last year from Democrat or split (between houses) to Republican;

(f) an interaction between the Republican governor and the Republican legislature indicator variables;

(g) an interaction between Republican governor and the Democrat legislature indicator variables (note that the omitted interaction category is Republican governor and a split legislature dummy);

(h) the reelection of an incumbent governor last year.

Data for these political variables come from the Statistical Abstract of the United States (U.S.

[11] We exclude Alaska, Hawaii, and the District of Columbia because of missing data for some of the weighting matrices and, for Alaska and Hawaii, because their great geographical distance to other states strains the notion of "neighboring states."

Census Bureau, Various Years).

IV. Estimation Issues

A. The Estimating Equation

The main objective of our empirical work is to identify the slope of the reaction function for state capital tax policies. We focus primarily on the investment tax credit rate (ITC) and the corporate income tax rate (CIT), but extend the results to the three other tax variables displayed in Figures 3 and 4 -- the tax wedge of capital, the average corporate tax rate, and capital apportionment weight. The strategic tax competition model developed in Section II implies that the reaction function can be represented by the following specification,

$$\tau_{i,t} = \alpha\tau^{f}_{i,t} + x_{i,t}\beta + u_{i,t}, \tag{7}$$

where $\tau_{i,t}$ is a tax variable for state *i* at time *t*, $\tau^{f}_{i,t}$ is the tax variable for the foreign states constructed as a spatial lag per equation (6), $x_{i,t}$ is a vector of control variables, $u_{i,t}$ is an error term, and the scalar α and vector β are parameters to be estimated. An immediate implication of the strategic tax competition model is that $\tau^{f}_{i,t}$ will be endogenous, an issue discussed in detail in Section IV.C. There are five control variables in total. The PREFERENCES and state GDP growth variables are time lagged one period to avoid estimation problems arising from simultaneity. POPULATION is entered contemporaneously. As suggested by the theoretical model, 1st order spatial lags of the economic and demographic control variables capture the impact of foreign variables on the location of capital and ultimately the setting of tax rates.

We expand this basic specification used in the tax competition literature in two important ways. First, we allow for the possibility that the impact of the key tax competition variable may be distributed over several time periods. This delayed impact may be due to various adjustment frictions and/or complicated interactions due to strategies played by states in a dynamic setting. The introduction of time lags of competitive states' tax policy, $\tau^{f}_{i,t-n}$, recognizes that the driving force behind a non-zero reaction function slope is the mobility of capital, which occurs gradually over several years. Appendix D derives a distributed lag econometric equation that captures this gradual response by combining a static tax reaction function with a partial adjustment model.

Second, our specification of the error term is new to the study of state tax policy (to the best of our knowledge) and has a generalized two-way error component structure that allows for heterogeneous cross-section dependence (CSD) among states,

$$u_{i,t} = \varphi_i + \gamma_i f_t + \varepsilon_{i,t} , \tag{8}$$

where φ_i is a time-invariant state-specific effect, $\varepsilon_{i,t}$ is a time-varying state-specific shock independent of $x_{i,t}$, f_t is an unobserved time-specific effect (f_t may be a vector), and γ_i is a state-specific aggregate factor loading. The $\gamma_i f_t$ term allows for heterogeneous CSD among the states that may be important. All states are affected by common aggregate shocks such as energy prices, federal and foreign tax policies, globalization pressures, and U.S. macroeconomic conditions. These aggregate shocks are represented by f_t. However, the impact (direction and magnitude) of these aggregate shocks may vary by state. For instance, changes in energy prices may have different effects on New England states with no energy production than on those states involved in the production of oil (e.g., Oklahoma and Texas) or biofuels (e.g., Illinois and Iowa). These differential responses are captured by the state-specific factor loadings, γ_i. The conventional time fixed effects (TFE) model is a special case of this framework and is obtained from equation (8) when $\gamma_i = \gamma$ for all *i*.

These two considerations lead to the following specification of our estimating equation,

$$\tau_{i,t} = \alpha_0 \tau^f_{i,t} + \sum_{n=1}^{N} \alpha_n \tau^f_{i,t-n} + x_{i,t}\beta + \varphi_i + \gamma_i f_t + \varepsilon_{i,t} \ . \tag{9a}$$

For convenience, we denote the sum of the coefficients on the current and lagged values of the foreign states' tax variable by α, which represents the long-run slope of the reaction function,

$$\alpha \equiv \sum_{n=0}^{N} \alpha_n \ . \tag{9b}$$

The strategic tax competition model necessarily implies that the three shocks – φ_i, $\varepsilon_{i,t}$, and $\gamma_i f_t$ – are correlated with tax policy in the foreign states, $\tau^f_{i,t}$. We address the resulting estimation problem in the following three ways. First, φ_i is modeled as a state fixed effect.[12] Second, $\gamma_i f_t$ is modeled using the Common Correlated Effects (CCE) estimator introduced by Pesaran (2006) to be discussed in Section IV.B. Third, the correlation between $\varepsilon_{i,t}$ and $\tau^f_{i,t}$ is accounted for by projecting the latter variable on a set of instruments, $z_{i,t}$; endogeneity issues will be discussed in Section IV.C. Our implementation of the instrumental

[12] State fixed effects capture, among other channels of influence, the impact of state size on capital income tax rates (Haufler and Wooton, 1999).

variables estimator is somewhat complicated by the CCE estimator, and we will address this computational problem in Section IV.D.

B. The Common Correlated Effects (CCE) Estimator

The CCE estimator is an important innovation for analyzing tax competition because it allows states to have heterogeneous responses to aggregate shocks.[13] Such common shocks are usually controlled for in panel studies with time fixed effects. As discussed above with respect to energy prices and similar aggregate factors, the assumption that all states are affected identically by aggregate shocks is restrictive and may bias all estimated coefficients. Of particular concern is the possibility that states' differential responses to aggregate shocks are correlated across space in a manner similar to the spatial pattern of capital mobility and hence tax competition. Heterogeneous responses could be accounted for by Seemingly Unrelated Regression, but this framework is not feasible when the number of cross-section units exceeds 10. The CCE estimator, on the other hand, is feasible for panels with a large number of cross-section units and it accounts for the unobservable $\gamma_i f_t$ by including cross-section averages (CSAs) of the dependent and independent variables as additional right-hand side variables, all multiplied by γ_i for a given state. If the γ_i's are constrained to be 1 for all *i*, the specification would be equivalent to transforming the data by demeaning each variable with respect to its CSA, the standard way of controlling for time fixed effects with the least squares dummy variables estimator. For the purposes of comparison to prior studies, we also will present time fixed effects estimates (TFE) that do not control for aggregate shocks; in this case, $\gamma_i = 0$.

C. Endogeneity and Instrumental Variables

The theory of tax competition has the strong implication that $\tau^f_{i,t}$ will be correlated with shocks to $\tau_{i,t}$ appearing in the error term. We address this endogeneity problem with instrumental variables (IV).[14] The endogenous $\tau^f_{i,t}$ variable is projected on a set of instruments,

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[13] The use of the CCE estimator in spatial panel models is not yet common. Pesaran and Tosetti (2011), however, show that the CCE delivers consistent and asymptotically normal parameter estimates in a spatial autoregressive panel model. That model can be transformed (under suitable regularity conditions) into a panel model with a spatially lagged dependent variable. See Pesaran and Tosetti (2011, Section 3) and Elhorst (2014, Chapter 4) for reviews of the literature on dynamic spatial panel models.

[14] Instrumental variables is one of two approaches typically used to estimate spatially autoregressive models. The other is maximum likelihood (e.g., Case, Hines, and Rosen, 1993), which is far more computationally intensive. See Brueckner (2003) for an extensive discussion of the econometric issues associated with identification of spatially autoregressive models in the context of tax competition and Pesaran (2006, Section 1) for a general review of estimation strategies.

described below. The fitted value, $\hat{\tau}^f_{i,t}$, then replaces $\tau^f_{i,t}$ in equation (9a).[15] We treat time lags of τ^f_i as exogenous, based on the assumption that past tax rates are pre-determined, and hence (conditional on state fixed effects) cannot be affected by current tax rates.

A common challenge in the empirical tax competition literature is to identify a set of appropriate instruments from the very large pool of potential instruments. Tax competition theory, as well as spatial econometric analysis (e.g., Kapoor, Kelejian, and Prucha, 2007), typically suggest that spatial lags of the control variables should be appropriate instruments. The latter consist of voter preference variables for the foreign states representing political outcomes for the executive and legislative branches. The political party affiliations of and interactions among the governor and state legislators should provide good proxies for preferences (Besley and Case, 2003; Snyder and Groseclose, 2000; Reed, 2006). These variables should be highly correlated with the foreign tax variable and uncorrelated with shocks to the home tax variable. The latter property might be compromised by national "political waves" (e.g., the Reagan Revolution) that affect all states more or less the same or by regional effects (e.g., similarities among Southern states). These potential correlations are accounted for by the time and state fixed effects, respectively. Thus, we instrument for changes in tax rates in foreign states using changes in the political party affiliations in those states, while conditioning on changes in political party affiliations in the home state. Changes in foreign states' political party control, holding fixed the home state's party control and state and time fixed effects, will be valid instruments so long as home state policymakers do not change home tax policy in direct response to changes in political party control in other states.

The potential set of instruments for a given tax variable indexed by τ for state *i* at time *t*– $Z_{\tau,i,t}$ – is constructed from spatial lags of the conditioning variables.[16] We consider 1st and 2nd

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[15] Since $\hat{\tau}^f_{i,t}$ is a generated regressor, we have investigated whether adjusting the standard errors with the procedure of Topel and Murphy (1985) has a notable effect on the standard errors. The adjustment turns out to have very little impact, and hence we do not include this adjustment in the results shown in this paper. Moreover, for testing the null hypothesis that the coefficient on $\hat{\tau}^f_{i,t}$ equals zero, no adjustment is necessary (Pagan, 1984).

[16] An interesting issue related to the proper choice of instruments for a panel model with two-way fixed effects is the potential "Nickell bias" (Nickell (1981)). As is well known in time-series models, the within IV estimator with predetermined variables (e.g., time lagged endogenous variables) is biased in finite-T samples because the predetermined variables are correlated with the within-transformed error term. In principle, this suggests that time lags of included instruments are invalid. However, what is not generally recognized is that there also is a parallel (or perhaps "perpendicular") finite-N bias coming from the spatial dimension. The two-way within estimator also transforms the error to sweep out time fixed

order spatial lags of the eight voter preference variables defined in Section III. This procedure generates a $Z_{\tau,i,t} = \left\{z^1_{\tau,i,t}, \ldots, z^{16}_{\tau,i,t}\right\}$ containing 16 candidate instruments. Unfortunately, IV estimators are known to be biased in finite samples when a large number of instruments are used (Hansen, Hausman, and Newey, 2008).

To avoid this bias, we adopt the following search procedure to obtain an optimal instrument set for each of our tax variables.[17] We form candidate instrument sets corresponding to all possible combinations of 1st order and 2nd order spatial lags of the voter preference variables, with the restriction that, if a candidate set contains the 2nd order spatial lag, the corresponding 1st order spatial lag must also be contained in the candidate set. Given that we consider eight preference variables, this procedure yields just over 1,000 candidate instrument sets. For each candidate set and for a given tax variable, we estimate the two-way fixed effects IV model and choose the instrument set that is valid (or, more precisely, not invalid) and has the best first-stage fit, the latter determined by the minimum eigenvalue (Cragg-Donald) statistic.[18] For instance, for the model with ITC as the dependent variable and containing the contemporaneous and three lags of the tax competition variable, the instrument set yielding the highest first-stage fit consists of just two variables -- the 1st order spatial lag of the legislature majority party and the 1st order spatial lag of whether an incumbent governor was reelected last year. For the model with CIT as the dependent variable and again containing τ^f_{t-n} (n=0,3), the chosen instrument set is similar -- the 1st order spatial lag of the interaction between governor party and legislature majority party and the 1st order spatial lag of whether an incumbent

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effects that may be correlated with *spatial* lags of the included instruments, thus invalidating such spatial lags as instruments. It is important to keep in mind, however, that both biases vanish as T or N gets large and the rate of convergence is rather rapid. Thus, these potential problems do not arise in our dataset with T and N dimensions of 42 and 48, respectively.

[17] Ideally, we would select an optimal set of instruments with a procedure that allows us to assess instrument relevance and validity simultaneously. To the best of our knowledge, there are no such formal statistical tests for choosing instruments (or moment conditions). For example, the moment selection procedures of Andrews (1999) and Andrews and Biao (2001) focus on instrument validity and maintain instrument relevance, while instrument selection procedures such as Donald and Newey (2001) focus on relevance and assume validity. Absent such a procedure, we remove candidate instrument sets that are invalid, where the latter condition is assessed with Hansen's J-statistic evaluated at the 10% level. In our particular application, the absence of a procedure for assessing instrument relevance and validity simultaneously is not important, as our results are completely robust to dropping instrument validity restrictions (cf. fn. 18).

[18] Optimal instrument sets are identified separately for models without lags and with three lags of $\tau^f_{i,t}$ The latter optimal instrument set is used for all models containing lags of $\tau^f_{i,t}$.

governor was reelected last year.[19] While we are not interested here in formal hypothesis testing of instrument relevance, it is interesting to evaluate the null hypothesis of instrument irrelevance in terms of the 5% critical values presented in Table 1 of Stock and Yogo (2005); for seven or fewer excluded instruments and a bias greater than 10%, the critical value is 11.29. The instrument sets selected by our algorithm (one each for the five tax policies we analyze) all exceed this critical value. The optimal instrument set thus identified for a given tax variable is labeled $Z^{*}_{\tau,i,t}$.

D. The General Specification and Implementation

The above considerations lead to the following general specification that is the basis of the estimates to be reported in Section V,

$$\begin{aligned}\tau_{i,t} = {} & \alpha_0 \hat{\tau}^{f}_{i,t} + \sum_{n=1}^{N} \alpha_n \tau^{f}_{i,t-n} + x_{i,t}\beta + \varphi_i + \varepsilon_{i,t} \\ & + \gamma_i \left(\bar{\tau}_t - \alpha_0 \bar{\hat{\tau}}^{f}_{t} - \sum_{n=1}^{N} \alpha_n \bar{\tau}^{f}_{t-n} - \bar{x}_t \beta \right),\end{aligned} \tag{10}$$

where the bar above a variables denotes its CSA.[20]

The CCE model is nonlinear in parameters (as shown in the second line of equation (10) containing the CSA terms), which complicates its implementation. There are at least three ways to estimate this model. The first approach ignores the nonlinear restrictions imposed on the model by simply allowing each of the CSA terms to have a separate, state-varying coefficient.

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[19] When CIT is the dependent variable, the Hansen J-test validity screen does not bind, meaning that the instrument set with the highest first-stage fit generates a Hansen overidentifying restrictions J-test statistic less than critical values at conventional levels of significance. For the ITC, there are a small number of instrument sets yielding higher first-stage fits but not satisfying the overidentifying restrictions screen. The empirical results for the reaction function are robust to using these alternative instrument sets. Indeed, out of 1003 candidate instrument sets for the ITC model, 95.2% yield a negative and statistically significant α; none yields a positive and statistically significant α.

[20] In general, the CSAs in the CCE estimator are formed with a set of state weights (note that these weights are unrelated to the state-pair weights used to construct the tax competition variable in equation (6)). As shown by Pesaran (2006, p. 975), the asymptotic properties of the CCE estimator are invariant to the choice of the CSA weights. The empirical work reported here is based on equal weighting for all j. As a robustness check, we construct state weights as the inverse of state j's average distance between all other states. Thus, a state like Washington in the northwestern corner of the continental United States gets less weight than a central state like Iowa. We find that the results are robust with respect to the baseline results to be presented in Tables 1, 2, and 3. In particular, the estimated slopes of the reaction functions for the ITC and CIT fall (in absolute value) by less than one standard error. Additionally, the result of a positive and significant slope without time lags of τ^{f} is unaltered by the use of the alternative weighting for both tax variables.

This can be implemented by interacting state dummies with each of the CSA terms and including all of these interactions, along with the other variables of the model (those in the first line of equation (10)), in a linear least-squares regression. Such a regression is perfectly feasible but quite inefficient, as it involves estimating a very large number of nuisance parameters. In our case, with 48 states, 5 control variables, and contemporaneous plus up to 4 lags of $\hat{\tau}^{f}_{i,t}$, we would estimate 586 parameters. We refer to this estimator as the "unrestricted/inefficient CCE" estimator.

A second possible way of estimating this model is via a nonlinear estimator such as nonlinear least squares or maximum likelihood. However, even with the restrictions imposed, there are still a fairly large number of parameters to estimate, and nonlinear estimators may have difficulty converging.

A third approach, and our preferred one, is to first obtain consistent estimates of γ_i, insert these $\hat{\gamma}_i$'s into equation (10), and then estimate the resulting parsimonious model via linear least squares. Specifically, we implement the following three-step procedure (Appendix E presents a more formal treatment of this procedure):

– Step 1: Estimate the linear, unrestricted CCE estimator (with the γ_i's set equal to 1.0) to obtain consistent (but inefficient) estimates of α_0, α_n's, β's, and φ's (state fixed effects). (Number of estimated parameters = 586.)

– Step 2: Use these estimates as initial values for the α_0, α_n's, and β's that pre-multiply the CSA terms (i.e., those on the second line of equation (10)). Obtain new estimates of the α_0, α_n's, and β's from the main regressors (i.e., those on the first line of equation (10)) and use them as the α_0, α_n's, and β's on the second line (the γ_i's are also estimated at each iteration). Iterate until α_0, α_n's, and β's in 1st and 2nd lines converge (the convergence criterion is that each individual parameter estimate is within 1% in absolute value of its previous value). At this point, the model yields consistent and efficient estimates of γ_i. (Number of estimated parameters = 106.)

– Step 3: Impose the $\hat{\gamma}_i$ from step 2. Estimate the resulting linear model via least squares to obtain consistent and efficient estimates of α_0, α_n's, β's, and φ's. (Number of estimated parameters = 58.)

We refer to this three-step estimator as the "efficient" or "restricted" CCE estimator. It should be emphasized that the purpose of imposing the CCE parameter restrictions is for efficiency. Consistent estimates can also be obtained from the "unrestricted/inefficient" estimator in step 1. Thus, while most of the results we report below are obtained with the efficient CCE estimator, we also compare these results to those from the inefficient CCE estimator in Section V.D.

V. Empirical Results

A. Baseline Results

Tables 1 through 3 contain the core results of the paper. The estimates are based on the Common Correlated Effects (CCE) Instrumental Variables estimator. The instruments are a subset of foreign political preference variables and are selected using the procedure described in Section IV.C. We also note that these instruments have a strong first-stage fit, as indicated by the Minimum eigenvalue statistic that are shown at the bottom of Tables 1 and 2 and are well above standard critical values for weak instrument bias (around 11.0, per Stock and Yogo, 2005).

In all regressions, standard errors are robust to heteroskedasticity and are clustered by year to account for the effects of any residual spatial dependence in the error term.

Table 1 presents the results of estimating equation (10) for the investment tax credit (ITC) with cross-section dependence accounted for by the CCE estimator and with various time lags of the spatially lagged tax variable. Column A contains estimates for a static model (i.e., no time lags of $\tau^{f}_{i,t}$), while Columns B to E incrementally add up to four time lags of the foreign tax variable.

Consistent with most previous empirical studies of tax competition, we find that the static model yields a reaction function slope that is positive and statistically significant at conventional levels. In fact, the point estimate is quite large. A reaction function slope outside the unit circle would be unstable, suggesting a lack of convergence to a steady-state equilibrium set of tax rates across states.

The sign of the reaction function, however, flips to negative when time lags of the spatially lagged tax variable are introduced. Column B adds the first time lag, $\tau^{f}_{i,t-1}$, to the specification. The sum of the two coefficients on $\tau^{f}_{i,t}$ and $\tau^{f}_{i,t-1}$ is now negative and statistically significant at the 1% level. This sum, α, is an estimate of the long-run slope of the reaction function. Including additional time lags of $\tau^{f}_{i,t}$ yields very similar long-run slope estimates, as shown in Columns C to E.

One interesting aspect of these results is that the coefficients on the contemporaneous value and time lags of the spatially lagged tax variable have different signs. Taken literally, this implies that states react negatively to out-of-state tax changes in the first year and then backtrack to some extent in the following years. This pattern may well reflect the complexity of a dynamic game among many players, and it neither confirms nor rejects any aspect of our model, which focuses on long-run equilibrium. It simply suggests that states may not move monotonically to the new equilibrium after a shock to out-of-state taxes and that a proper specification of the estimating equation needs to include time lags.

Table 2 repeats this exercise with the ITC replaced by the corporate income tax (CIT) rate. The results found for the ITC – a positive slope flipping to a negative slope when time lags of the spatially lagged tax variable are included – also hold for the CIT. However, for the CIT, the p-values for the slope coefficients are larger than those in Table 1; in some cases, the p-values slightly exceed the conventional 0.10 level.

The estimated coefficients on the control variables in Tables 1 and 2 also warrant a brief discussion. The coefficient on PREFERENCES suggests that states where voters tend to vote Republican have lower values for the ITC and CIT. This result could be consistent with a "libertarian" or "tea party" type of Republicanism that favors both low investment subsidies and low corporate taxes and that recognizes that the former may need to be financed by the latter. The economic control variables -- $\mathrm{GDPGROWTH}_{i,t-1}$ and $\mathrm{GDPGROWTH}^{f}_{i,t-1}$ -- have no significant effect on the ITC or CIT. Lastly, both home and foreign state populations negatively affect both tax variables.

Table 3 summarizes the variation in the estimated long-run slope of the reaction function, α, due to the tax policy instrument, the number of time lags of the spatially lagged tax variable, and controls for aggregate shocks. The CCE estimator allows for heterogeneous responses to aggregate shocks across states, the time fixed effects (TFE) estimator allows only for homogeneous responses across states, and the estimator with no time fixed effects (NTFE, a one-way state fixed effects estimator) does not allow for any response to aggregate shocks.

Four important findings emerge. First, allowing for both time lags of the spatially lagged tax variable and heterogeneous responses to aggregate shocks have a marked impact on the estimated slope of the reaction function. Relative to models that use alternative specifications, the slope switches from significantly positive to significantly negative.

Second, once we control for at least one time lag, we find that, for our preferred CCE model, the slope estimates are not very sensitive to the number of additional time lags included. For the ITC model, the slope estimate varies between -0.619 and -0.689 and is always statistically significant. A similar pattern emerges for the CIT model when we include one, two, or three time lags of the spatially lagged tax variable -- the slope varies between -0.220 and -0.313 and the associated p-values hover around 0.10. When a fourth lag is included, the slope is less stable, rising to -0.567. For the remainder of the paper, we will treat the three-lag model as our preferred specification for both tax variables.

Third, including time lags of the spatially lagged variable is an important innovation in this paper. We evaluate the null hypotheses that these time lags are jointly insignificant (i.e., $\alpha_1 = ... = \alpha_n = 0$ for n=1,4) with a joint F/Wald test.[21] For the ITC, the p-values are less than 0.05 for all four models. For the CIT, the p-values are below 0.10 for models with one or four time lags, and slightly above 0.10 for models with 2 or 3 time lags. These results suggest the importance of including time lags of the spatially lagged ITC variable and, to a lesser extent, the spatially lagged CIT variable.

Fourth, in unreported results, we find considerable variation in the estimated state-specific factor loadings on the aggregate shock, $\hat{\gamma}_i$. The null hypothesis of equality of the 48 $\hat{\gamma}_i$'s is easily rejected by a F/Wald test relative to conventional significance levels. The rejection of homogeneity suggests that the standard time fixed effects model is misspecified with respect to our data.

Aside from these findings, the key economic result from Table 3 is that the slopes of the reaction function for ITC and CIT are negative. At conventional levels of significance, the ITC slope is significant, while the slope for CIT is marginally insignificant. Additionally, the larger (in absolute value) slope for ITC confirms the second implications of the theoretical model. As shown in equations (4) and (5), the absolute value of the slope of the reaction function is expected to increase with capital mobility. For the CCE model with three time lags, the estimated slopes are −0.619 and −0.220 for the ITC and CIT models, respectively. These results are consistent with our theoretical model and the targeting of less mobile (old and new) capital by the CIT and more mobile (only new) capital by the ITC, though, as we shall see below, this result is not always robust.

As a check on the plausibility of these econometric results, we calibrate the capital

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[21] We also have tested the equality of the coefficients on the contemporaneous and lagged values of τ_i^f, via a Wald test. For the ITC regressions, the equality of coefficients is rejected at below the 0.001 level for all four models in Table 1 (i.e., one, two, three, or four lags). For the CIT regressions, the equality of coefficients is rejected at below the 0.05 level for the 3-lag specification, but not for the other specifications (the p-values in those cases range from 0.12 to 0.37). Thus, we argue this time-averaged model is strongly rejected by the data for the ITC and weakly rejected for the CIT. We thank one of the anonymous referees for suggesting this test.

mobility parameter, $-\eta_{K,\tau}$, the elasticity of capital with respect to a tax rate. Estimates of α, our theoretical model of the estimated reaction function (equation (3)), and a set of assumed parameter values (see fns. 9 and 22) imply that the elasticities for the ITC and CIT are 3.25 and 0.85, respectively.[22] These figures can be adversely affected by the uncertainty associated with the assumed parameter values. However, their <u>ratio</u> depends only on a transformation of the $\hat{\alpha}$'s and is approximately 4.00. Taken together, these figures suggest that new capital (targeted by the ITC) is substantially more mobile than old capital (targeted by the CIT).

In sum, our baseline results document that, when we allow for time lags of the spatially lagged tax variable and heterogeneous responses to aggregate shocks, the slope of the reaction function is negative. Incorporating both of these elements into the econometric model is crucial for specifying the estimating equation properly and avoiding the erroneous conclusion of a positively sloped reaction function. Time lags reflect that capital mobility among states is not instantaneous because of adjustment frictions and/or dynamic strategic interactions, and thus it occurs over more than one year. Allowing for aggregate shocks controls for common incentives that will lead states to act more-or-less synchronously. The positive slopes obtained when aggregate shocks are ignored accord with anecdotal evidence of positive reactions among states and the data in Figure 1. However, in order to assess accurately the response of home state tax policy to foreign state tax policy, we must control for aggregate shocks and allow a given shock to impact states differently. With proper conditioning, the estimated slope of the reaction function is negative and larger (in absolute value) for the ITC that targets new capital relative to the CIT that targets both new and old capital.

B. Additional Control Variables

In this and the next two subsections, we assess the robustness of the above results to additional control variables, alternative variable definitions and samples, and alternative specifications. The instrument sets are the same as used in the baseline model. A summary of results are presented in Table 4, whose columns contain the α's for the static model without time fixed effects in columns A and C and our preferred CCE model (with time lags of the spatially lagged tax variable) for the ITC (α_{ITC}) and CIT (α_{CIT}) in columns B and D.

The baseline results are repeated in panel A. We focus on three key results: (1) for static

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[22] See fn. 9 for the assumed parameter values. Additionally, we assume that $\eta_{\zeta,y} = 2.00$; the calibrated $-\eta_{K,ITC}$'s reported in this paragraph are proportional to $\eta_{\zeta,y}$. The $\hat{\alpha}$'s are averages of the four estimates in columns (B) to (E) of Tables 1 ($\bar{\hat{\alpha}}_{ITC} = 0.657$) and 2 ($\bar{\hat{\alpha}}_{CIT} = 0.334$).

models with time fixed effects, α_{ITC} and α_{CIT} are positive and significant below the 1% level; for the CCE with time of the spatially lagged tax variable, (2) α_{ITC} and α_{CIT} are negative and significant and (3) $|\alpha_{ITC}| > |\alpha_{CIT}|$. Result (1) is confirmed in all 12 estimates presented in Table 4 and will not be discussed further.

Our first robustness check is presented in row 1 of panel B and evaluates whether changes in the industry mix over time might affect the slope estimates. The state fixed effect captures industry mix only insofar as it is time invariant. We re-estimate our preferred baseline models (using the CCE estimator and including 3 lags of $\tau^{f}_{i,t}$, as in column (D) of Tables 1, 2, and 3) with $\tau_{i,t}$ equal to either ITC or CIT and including the manufacturing sector's share of state GDP, lagged one period to avoid endogeneity issues. Both $|\alpha_{ITC}|$ and $|\alpha_{CIT}|$ by between 0.44 and 0.53 percentage points, and they remain far from zero.

Our second robustness check explores the sensitivity of the empirical results to controlling for other home state tax policies. All of the empirical work reported so far examine how states vary a given capital tax policy in response to changes in that same capital tax policy in competing states. This focus on a single tax policy at a time is consistent with the approach taken in the literature, and also avoids introducing potential endogenous controls, but there is the possibility that a change in the foreign capital income tax rate might result in changes in several home taxes simultaneously. Incorporating multiple tax instruments into a coherent theoretical model has, to the best of our knowledge, not been achieved in the literature and is beyond the scope of the current study.

Nonetheless, it may be informative to consider empirically whether a given capital tax policy's estimated reaction slope changes if we control for other prominent tax policies – the other capital income tax rate and the marginal income tax rate for the median household (PERS). Since data on PERS is only available after 1976, we first re-estimate the baseline models for the post-1976 sample. The pattern of results is similar to those based on the full sample, though, relative to the baseline, $|\alpha_{ITC}|$ rises and $|\alpha_{CIT}|$ falls and is quite close to zero. We then condition on the complementary class of tax variables (which we label CC). If these additional tax variables provide quantitatively important channels through which a state reacts to a foreign states capital tax policies, we would expect their introduction to substantially alter the slope of the estimated reaction function. We consider two models: (1) $\tau_{i,t} = ITC_{i,t}$,

$CC_{i,t} = \{CIT_{i,t}, PERS_{i,t}\}$; (2) $\tau_{i,t} = CIT_{i,t}$, $CC_{i,t} = \{ITC_{i,t}, PERS_{i,t}\}$. As shown in row 2, the slope parameters prove very robust. While we have not controlled for all tax variables, there is no evidence in Table 4 suggesting instability in this dimension.

Our third, fourth, and fifth robustness checks continue to examine the role played by the fiscal environment and the extent to which stresses on the state's overall fiscal position might constrain tax setting behavior. We introduce ad seriatim three control variables measuring fiscal pressure – government expenditures as a share of state GDP (lagged one year), the population share of residents 20-64 years of age (who contribute positively to the state's fiscal position), and one-year lagged corporate tax revenues as a share of state GDP.[23] The results in rows 3, 4, and 5 confirm that α_{ITC} is negative and statistically far from zero. While α_{CIT} also continues to be negative, its value fluctuates. When fiscal pressure is measured by government expenditures, $|\alpha_{ITC}| < |\alpha_{CIT}|$, thus reversing our third key finding.

C. Alternative Variable Definitions And Samples

Our sixth and seventh robustness checks investigate the extent to which our baseline results are sensitive to the definition of the foreign state tax policy. We repeat our main regressions using alternative weighting matrices to form the spatial lag of the foreign state tax variable, $\tau^f_{i,t}$ (cf. equation (6)). State capital tax policy may be sensitive to policies of states that are "economically close" rather than "geographically close," the latter quantified by our inverse distance metric. For example, two states that are equally distant from a given state may nonetheless differ in their economic impact because of their size or their trade flows. Thus, we construct two alternative weighting matrices to measure "economic closeness": inverse geographic distance multiplied by population and commodity shipments from home state *i* to foreign state *j*.[24]

The results are shown in rows 6 and 7 of Table 4. Using either alternative spatial weighting matrix, the baseline results of negative and significant slopes for the ITC and CIT reaction functions are strongly confirmed. The result that the CIT reaction slope is less steep than that of the ITC, however, is less robust to the nature of state interrelatedness. When spatial

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[23] We thank one of the reviewers for suggesting this set of robustness checks. The most direct approach to measuring fiscal pressure would be with government deficits. However, since virtually all states have restrictions on budgeting, deficits would not be very informative.

[24] Note that we only have commodity flow data for one year, so this alternative weighting matrix could be compromised by considerable measurement error.

weighting is based on population divided by distance, the ITC reaction slope is only slightly steeper than that of the CIT. When trade flows are used for spatial weighting, the CIT reaction slope is steeper.

Our eighth robustness check examines the sensitivity to extending the sample period from an end date of 2006 to 2011. We used the earlier date for our baseline results because we wanted to avoid the possibly distorting effects of the financial crisis and the Great Recession. As shown in row 8, lengthening the sample strengths our results concerning the slope of the reaction function, as both α_{ITC} and α_{CIT} are negative and significant at the 1% level. However, our third key finding is not sustained, as $|\alpha_{ITC}| < |\alpha_{CIT}|$.

In results not reported in Table 4, we also explore some additional sub-sample stability. The data in Figure 1 indicate that there was a rapid increase in ITC adoption between 1973 to 1977 and 1994 to 1999. We thus evaluate the extent to which the results are temporally sensitive by including dummy variables that are defined over these intervals and that enter in both levels and interacted with the contemporaneous and one period lagged values of the foreign tax rate. For the time periods other than these two intervals, the pattern of slope coefficients is robust, as $\alpha_{ITC} = -0.605$ and $\alpha_{CIT} = -0.139$, though only the former is significant. The slopes for the 1973-1977 interval are insignificant. However, for the 1994-1999 interval, $\alpha_{ITC} = -1.166$ and $\alpha_{CIT} = -0.441$, and both are precisely estimated. These results identify some temporal instability but are generally consistent with our three key results.

D. Alternative Specifications

The remaining robustness checks alter the specification in several ways. Our ninth robustness check estimates the baseline specification by OLS. While our instrument relevance and validity tests indicate that we are dealing with the endogeneity rather well, it is nonetheless possible that our estimates can be biased by the choice of instruments. The OLS results for the CCE estimator prove very robust, with both slope estimates reduced by about only 7%.

Our tenth robustness check assesses the sensitivity of our main results to time lags of all independent variables, as opposed to just the tax competition variable in our baseline model. Our preferred specification omits these additional time lags to conserve degrees of freedom, as each extra regressor requires another CSA term in the CCE estimator. Nonetheless, estimating this full specif1ication is feasible. The results are shown in row 10. Relative to the baseline results, both $|\alpha_{ITC}|$ and $|\alpha_{CIT}|$ rise sharply and are significant at the 1% level. The rise in the CIT slope is so large that the third key result is no longer supported.

Introducing a lagged dependent variable (LDV) is a parsimonious way to capture dynamics from all regressors. Our eleventh robustness check examines such a specification. However, a major drawback of a dynamic model that includes one LDV and no lags of the independent variables is that the sign of the long-run effect on a given independent variable is restricted to be the same as the sign of the short-run effect. This restriction emerges because the long-run effect is calculated as the coefficient on the independent variable divided by one minus the coefficient on the LDV, which is typically between 0 and 1.[25] The LDV model is nested within the preferred model described above when the latter has an infinite number of lags (see Appendix F).[26] Of course, an infinite-lag model cannot be estimated, but a restricted version, in which the coefficients on the independent variables for the first *N* time lags are unrestricted and the effects of lags beyond the *N+1* period are captured parsimoniously by the dependent variable lagged *N+1* periods, can be estimated. For our preferred specification (N = 3), the coefficients on the LDV lagged four periods are 0.294 and 0.362 for the ITC and CIT models, respectively, and are statistically far from zero. Estimates of the α's continue to be negative and significant: $\alpha_{ITC} = -0.814\ (0.183)$ and $\alpha_{CIT} = -0.690\ (0.289)$, and are consistent with our key empirical results.

Our twelfth and final robustness check compares the efficient and inefficient estimates from our three-step restricted CCE estimator. Recall that both procedures deliver consistent parameter estimates, but the inefficient procedure requires 10 times more estimated parameters (cf. Section IV.D). The pattern of results are similar to those for the efficient baseline model though, as expected, the standard errors are quite large.

E. Extensions

This subsection extends the core analysis by considering three additional measures of capital taxation. The first additional measure of capital tax policy we consider is the tax wedge on capital (TWC). All of the above analyses have measured $\tau_{i,t}$ using one of two statutory tax policies, the ITC or CIT. The TWC allows us to examine their combined effects by focusing on

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[25] This restriction can be seen by considering the formula for the long-run effect of a given variable in a lagged dependent variable model. The coefficient on any independent variable, call it α_0, represents the short-run effect of that variable. The long-run effect is given by $\alpha_0 / (1-\rho)$, where ρ is the coefficient on the lagged dependent variable and should be between 0.0 and 1.0. Thus, the long-run effect will always have the same sign as the short-run effect in a model that captures dynamics only with a lagged dependent variable. See Appendix G for further discussion.

[26] The use of an LDV also creates some econometric difficulties with correlations between the LDV and the state fixed effect (the "Nickell bias;" Nickell (1981), Devereux, Lockwood, and Redoano (2007)) and the LDV and a serially correlated error term (Jacobs, Ligthart, and Vrijburg, 2010).

that part of the user cost of capital that incorporates both of these policies (see fn. 1 and Appendix C for details). Estimates of the benchmark model but using TWC as the tax variable are presented in panel A of Table 5. While point estimates are generally larger than in Table 3, the key patterns that we observed previously remain with TWC -- models without aggregate effects or time lags of $\tau^{f}_{i,t}$ generate positive α's and the introduction of aggregate effects and time lags generates negative α's that are statistically different from zero at conventional levels.

The second additional tax policy measure is the average corporate tax rate ($ACT_{i,t}$). As we discuss in Section VI below, the statutory policies considered so far in this paper are the appropriate variables of interest in tax competition because they are the tax instruments that policymakers control directly. The average corporate tax rate, on the other hand, measures total state corporate tax revenues divided by a tax base and are largely beyond the control of policymakers. Though policymakers' choices regarding statutory policies influence this average rate, current economic conditions and other exogenous factors, especially the firm's choice of organization form, also have substantial effects.[27] Nonetheless, because average tax rate measures are often used in the empirical tax competition literature, we present results in panel B of Table 5 based on $ACT_{i,t}$ in order to draw comparisons with some prior results. The $ACT_{i,t}$ is the ratio of state corporate tax revenues to total state business income, the latter measured by gross operating surplus.

The $ACT_{i,t}$ results are mixed relative to the estimates based on statutory tax rates. We find that the estimated slope of the reaction function based on the $ACT_{i,t}$ is positive in a static model with or without time fixed effects. The results in Table 5 may partly explain why positively sloped reaction functions have been found previously in studies based on average taxes. As with the benchmark CCE model, the addition of a lagged value of $\tau^{f}_{i,t}$ yields a negative slope. However, the results are fragile; additional lags result in imprecisely estimated slopes. These results suggest that there can be a great deal of difference in estimated reaction function slopes when tax policy is measured by marginal and average tax rates, a finding consistent with the evaluation of statutory and average tax rates by Plesko (2003).

The third and final tax policy measure concerns another important, but less well-known,

[27] Regarding the sensitivity of organization form to corporate taxation, see Goolsbee (2004), Mackie-Mason and Gordon (1997), and Mooij and Nicodème (2008) for evidence across U.S. states, U.S. industries, and EU firms, respectively.

capital tax policy used by U.S. states, the Capital Apportionment Weight. The CAW is the weight that a state assigns to capital (property) in its formula for allocating a portion of a corporation's national income to that state and, per Figure 4, has fallen sharply over our sample period.[28] Unlike the ITC and CIT, changes in the CAW are somewhat difficult to interpret because an increase in the capital weight necessarily implies a decrease in the weights for the non-capital components in the apportionment formula; the net effect on incentives depends on the relative importance of capital and non-capital activity. With this caveat in mind, the results for the capital apportionment weight are shown in Panel C of Table 5. Again, the introduction of time lags of the tax competition variable, combined with controlling for aggregate shocks, results in a sign flip of the long-run reaction function slope from positive to negative. The absolute values of the slope point estimates for CAW are much larger than those for ITC or CIT. These results strongly suggest that the slope of the reaction function for CAW is negative and that, as with ITC and CIT, including time lags of the tax competition variable and controlling for aggregate shocks are important elements in a properly specified econometric equation.

VI. Previous Empirical Studies

The empirical literature on fiscal competition has grown considerably in recent years (see Devereux and Loretz (2013) and Revelli (2015) for recent surveys). However, the policy focus and methodologies used differ widely across studies. Among studies of "horizontal" (same level of government) competition, studies vary in whether they focus on expenditure policy or tax policy, and among tax policy studies, some focus on business taxes and some on consumer/personal taxes. In terms of our policy focus on business taxes, the current paper is most closely related to Overesch and Rincke (2009), Devereux, Lockwood, and Redoano (2008) and, to a lesser extent, Altshuler and Goodspeed (2015) and Hayashi and Boadway (2001). In contrast to our paper, Devereux, et al. and Hayashi and Boadway consider static models of

[28] In the United States, for the purposes of determining corporate income tax liability in a given state, corporations that do business in multiple states must apportion their national income to each state using formulary apportionment. The apportionment formula is always a weighted average of the company's and capital (property), payroll, and sales (with zero weights allowed). However, the weights in this formula vary by state, and there is no coordination among states. As shown in Figure 4, over the last forty years, states have increasingly moved toward decreasing the weight on capital, which usually is the same weight applied to payroll, thus increasing the weight on sales. This re-weighting aims to encourage job creation and investment in their state (and "export" the tax burden to foreign state business owners that sell goods and services in-state but employ workers and capital out-of-state). The capital weight can be thought of as a capital tax instrument with similar effects as the corporate income tax, though it receives relatively much less attention by the public than the CIT.

corporate tax competition. Altshuler and Goodspeed, on the other hand, consider the possibility that corporate tax competition across countries takes the form of a Stackelberg game, with the U.S. as leader, and then estimate a model whereby countries react to U.S. tax policy changes with a one-year lag. However, because U.S. tax policy is common to all other countries, they are unable to allow for common/aggregate shocks. All three of these studies find a positively sloping reaction function, as do we when we use the static model or omit controls for aggregate effects.[29]

Overesch and Rincke estimate a tax competition model using panel data on corporate income tax rates for EU countries. They control for time and country fixed effects, though they do not allow for common correlated effects. Similar to our results, they find that the estimated slope of the reaction function is positively biased if one omits time effects. However, while reduced, their estimated slope parameters remain positive after the addition of time fixed effects. A more significant difference in methodology between Overesch and Rincke and the current paper is the manner in which dynamics are modeled. Based on a partial adjustment model, Overesch and Rincke capture dynamics with a lagged dependent variable, which, as noted in Section V.B, restricts the sign of the long-run effect to be the same as the sign of the short-run effect. Our more general estimator allows for the possibility that the short-run and long-run effects have different signs. As shown in our above empirical results, such flexibility proves important for accurately estimating the reaction function slope.

An important contribution of our paper is to document the sensitivity of estimated reaction function slopes to the tax variable. Our preferred specification uses statutory tax variables because they are directly chosen by policymakers. Motivated by a tax competition model in which both capital and corporate income are mobile (the latter via transfer pricing), Devereux, Lockwood, and Redoano (2008) estimate a two-equation system with the statutory corporate income tax rate and the effective marginal tax rate (EMTR) on capital as dependent variables. For 21 OECD countries, they find a positive and significant slope for the statutory rate but a small and insignificant slope for the EMTR. These results are broadly consistent with our results for U.S. states when we estimate a similar static specification (cf. Table 3 (for ITC and CIT) and Panel A of Table 5 (for TWC)). Altshuler and Goodspeed (2015) and Hayashi and Boadway (2001) are somewhat less comparable to our study because they estimate reaction

[29] Empirically estimated reaction functions with negative slopes are rarely found in the economics literature. The only exceptions about which we are aware are the papers of non-capital tax rates by Brueckner and Saavedra (2001), who consider property tax competition among municipalities in the Boston metropolitan area, and Parchet (2014), who studies personal income tax competition among Swiss municipalities.

functions for the average effective corporate income tax rate – corporate income tax revenues divided by total corporate income (or GDP in Altshuler and Goodspeed) – rather than for statutory tax rates. Our results in Panel B of Table 5 suggest that there can be a great deal of difference in estimated reaction function slopes when tax policy is measured by marginal and average tax rates.[30]

Lastly, our paper is part of the recent strand of the tax competition literature emphasizing the importance of proper identification (see Revelli 2015). As stressed in Combes and Gobillon (2015) and Gibbons, Overman, and Patacchini (2015), spatial lag models in general, and used in tax competition studies specifically, typically face the identification issue known as the "reflection problem." Recent identification strategies have focused on studying natural experiments (e.g., Lyytikainen 2012), using quasi-experimental designs (such as spatial discontinuities as in, e.g., Agrawal (2015) and Parchet (2014)), or relying on theoretical guidance for exclusion restrictions (as we do in this paper).

VII. Summary and Conclusions

Motivated by strategic tax competition theory and based on state panel data from 1965-2006, this paper estimates a capital tax reaction function for several measures of capital tax policy. Our key and robust empirical finding is that the slope of the reaction function is negative. This result is consistent with the implications of our theoretical model of tax competition that the slope of the reaction function can be positive, negative, or zero depending on a key elasticity. We document that allowing for time lags of the spatially lagged tax variable and heterogeneous responses to aggregate shocks are vitally important in accurately estimating this slope. The results prove robust in several dimensions, including defining tax policy in terms of the tax wedge on capital or the capital apportionment weight. A second hypothesis following from our theoretical model -- tax policies targeting new, more mobile capital like the ITC should have a larger reaction function slope than policies targeting total (new and old) capital like the CIT – receives mixed support.

While these empirical results are striking given prior findings in the literature and the casual observation that state capital tax rates have fallen over time, they are not surprising. The negative sign is fully consistent with the qualitative and quantitative implications of the

[30] In Altshuler and Goodspeed, considering a Stackelberg game, countries are assumed to respond to tax policy of the leader country with a one-year lag. Their specification allows for a common time trend of global tax rates, but cannot control for aggregate shocks because time fixed effects would fully absorb leader-country tax rates.

theoretical model developed in this and other papers. The model illustrates how, if a state responds to a positive income shock by increasing spending on private goods relative to public goods, a tax increase in a foreign state (or more precisely, an income windfall resulting from the tax-induced capital inflow from the foreign state) reduces its own tax rate. The model highlights the crucial role played by the income elasticity of public goods relative to private goods. This elasticity depends on whether private goods are necessities or luxuries, a condition closely related to the validity of Wagner's Law. Our empirical findings suggest that, while state capital taxation has eased dramatically in recent decades, the downward pressure is not coming from tax competition – i.e., how states respond to each other – but from aggregate shocks impacting all states in more or less the same way. Rather than states "racing to the bottom" – a competition in which participants respond to each other's movements in the same direction -- our findings indicate that tax competition is better characterized by states "riding on a seesaw."

An important implication of this result is that calls for legislative, judicial, or regulatory actions aimed at restricting tax competition as a means of stemming the fall in state capital tax revenue or the mobility of capital are likely misguided. In fact, similar calls in the European Union might also be inappropriate.[31] If aggregate shocks, not tax competition, are driving the secular trends in capital taxation, both in the U.S. and Europe, public policies attenuating tax competition will do little to stop or reverse these trends.[32] This paper leaves open the question as to which aggregate shocks may be responsible for the decline in capital income tax rates documented in Figures 1 to 4. One possibility is shocks to the aggregate capital income share. Our theoretical model shows that the equilibrium tax rate is negatively related to the pre-tax capital income share (see Appendix B.2, equation (B.2-4)). The secular increase in this share is well documented for the United States (Elsby, Hobijn, and Şahin, 2013) and worldwide (Karabarbounis and Neiman, 2014; Piketty, 2014), and future work needs to examine the quantitative relations between these secular movements and state tax policy.

The finding of a negative-sloping capital tax reaction function has several implications for the strategic tax competition models. First, the non-zero slope provides support for the

[31] Sutter (2007, p. 124) argues that the Code of Conduct for business taxation was adopted by the EC Commission in 1997 in light of an "intense discussion about unfair tax competition among OECD and EC Member States in the late 1990s showing that national tax individualism ultimately leads to a harsh fiscal race to the bottom in attracting 'mobile' foreign industries and businesses."

[32] Nonetheless, there may well be other arguments for restricting tax competition. In particular, the canonical strategic tax competition models of Oates (1972), Zodrow and Mieszkowski (1986), and Wilson (1986) and others yield an equilibrium with sub-optimally low taxes and public services, irrespective of the slope of the reaction function.

empirical importance of strategic tax competition relative to other factors in tax setting behavior. The finding is a rejection of both the hypothesis that capital is immobile and the hypothesis that the supply of capital to the nation is perfectly elastic; either hypothesis implies a zero slope to the reaction function. Second, multi-stage or Stackelberg models of tax competition rely on a positively sloped reaction function for several results (Konrad and Schjelderup, 1999). The negatively sloped reaction function documented in this paper raises concerns about the existence, stability, and uniqueness of equilibrium in these classes of models. Third, tax coordination by a group of countries may lead to a fall in welfare if the tax reaction function of countries excluded from the group is negatively sloped (Vrijburg and de Mooij, 2016). Fourth, the negative slope also suggests that the theory of yardstick competition, a leading alternative theory of fiscal strategic interaction and one that predicts a positive-sloping reaction function, is either not an important force in the setting of capital tax policy or is dominated by the force of tax competition.[33] Future research in this field might well focus on whether similar methodological improvements as those employed in this paper could unearth evidence of negative sloping reaction functions in other areas of fiscal policy, such as personal taxation, in which yardstick competition is likely to be a stronger force.

[33] A negatively sloped reaction function allows us to avoid the observational equivalence problem between yardstick and tax competition noted by Revelli (2005).

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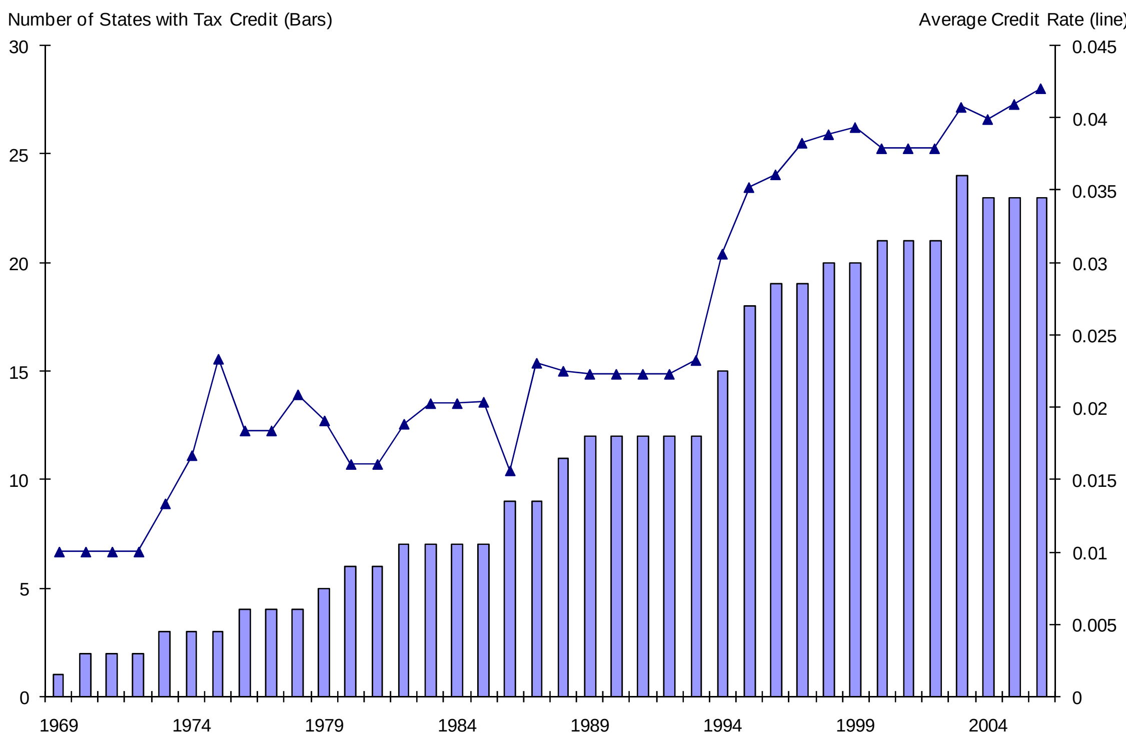
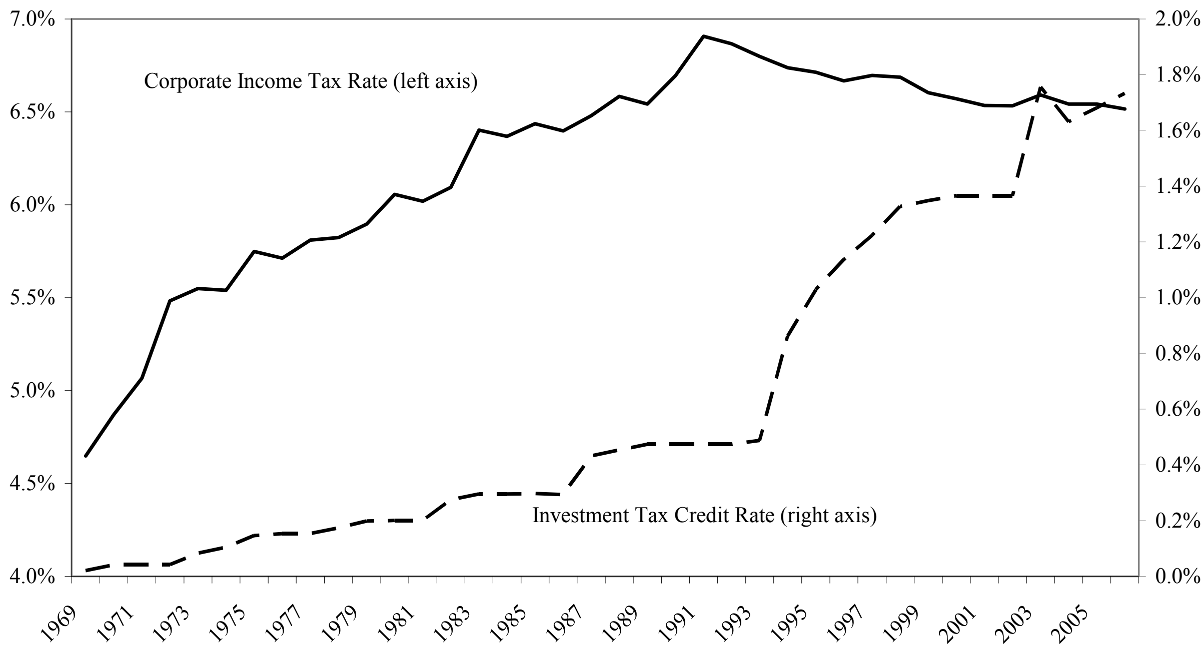
Figure 1. State Investment Tax Credit Rates

1969 To 2006



Notes to Figure 1: The number of states with an investment tax credit is indicated on the left vertical axis; the average credit rate (an unweighted average across only those states with a credit) is indicated on the right vertical axis. See Appendix C for details concerning the construction of the variables.

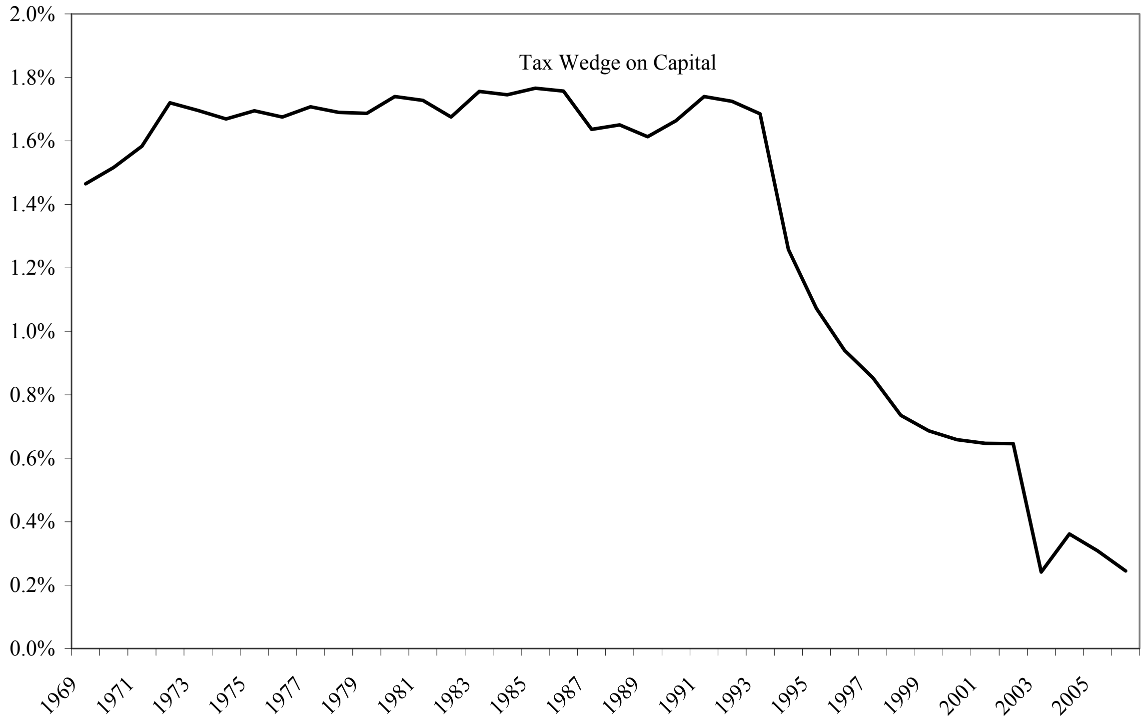
Figure 2. National Averages Of State Investment Tax Credit
And Corporate Income Tax Rates
1969 To 2006



Notes to Figure 2: Averages are calculated over all 50 states (unweighted) and exclude the District of Columbia. Both rates are measured by the top marginal rate. See Appendix C for details concerning the construction of the variables.

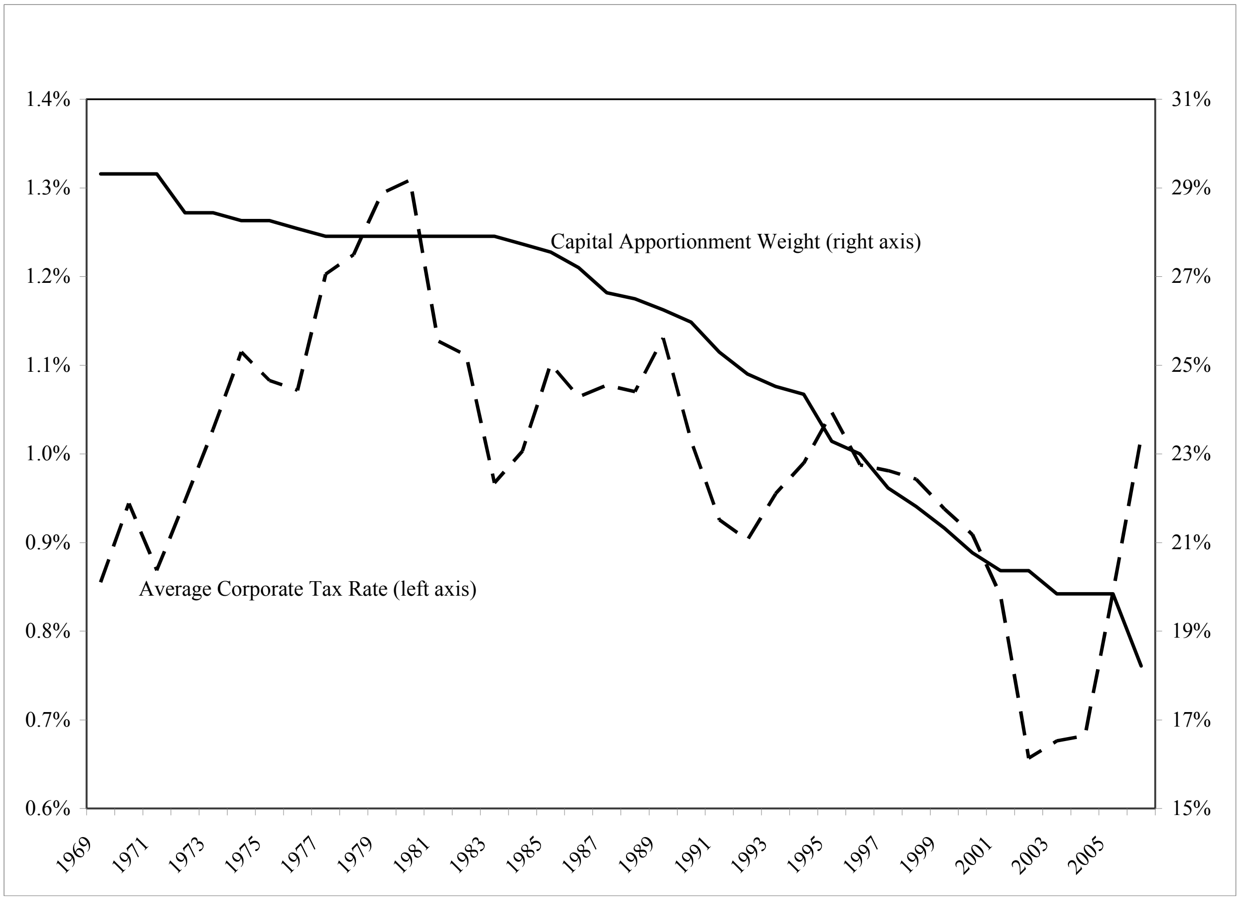
Figure 3. National Average Of State Tax Wedge On Capital

1969 To 2006



Notes to Figure 3: Averages are calculated over all 50 states (unweighted) and exclude the District of Columbia. See footnote 1 and Appendix C for details concerning the construction of the variable.

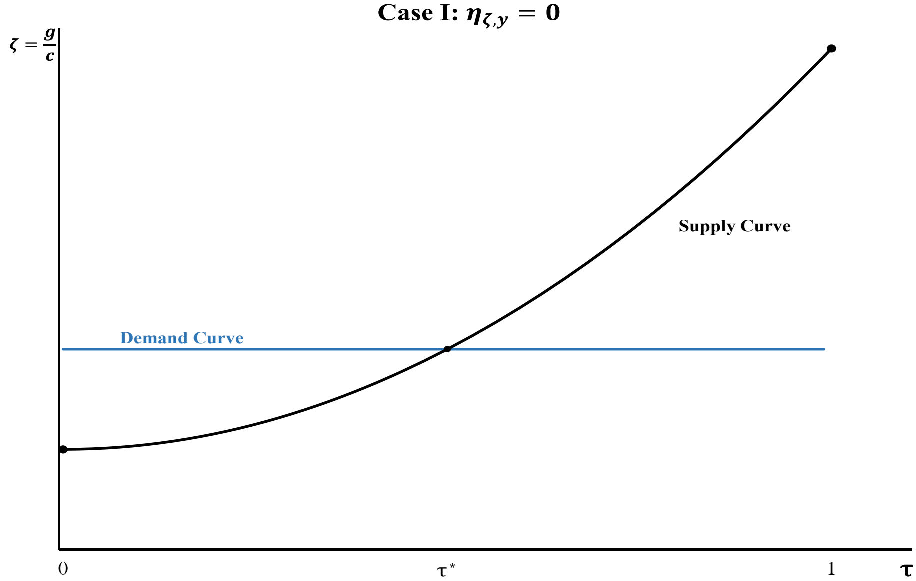
Figure 4. National Averages Of Capital Apportionment Weight And Average Corporate Tax Rate 1969 To 2006



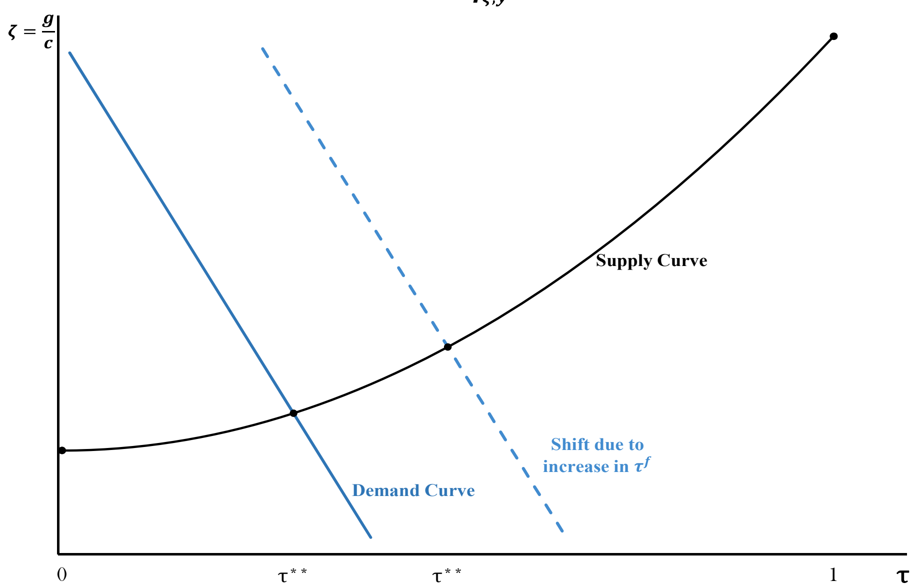
Notes to Figure 4: Averages are calculated over all 50 states (unweighted) and exclude the District of Columbia. See Appendix C for details concerning the construction of the capital apportionment weight variable. The average corporate tax rate variable is the ratio of state tax revenues from corporate taxes, severance taxes, and license fees to total state business income, the latter measured by gross operating surplus.

Figure 5. The Supply And Demand Of Relative Public Consumption

Case I: $\eta_{\zeta,y} = 0$



Case II: $\eta_{\zeta,y} > 0$



Case III: $\eta_{\zeta,y} < 0$

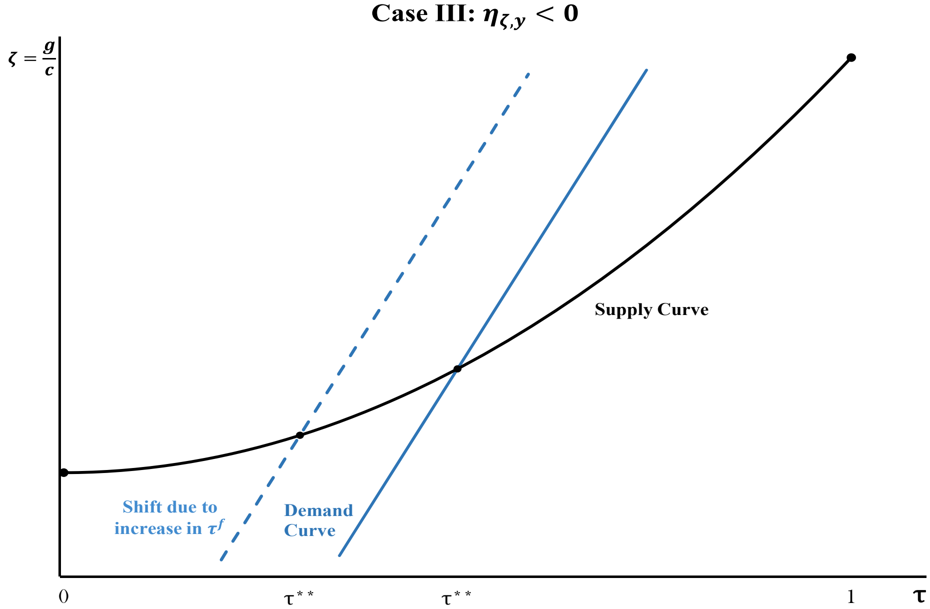


Table 1
Tax Policy (τ): Investment Tax Credit Rate ("New Capital")
Common Correlated Effects Pooled (CCE) IV Estimator and
Various Time Lags of Tax Competition Variable

	(A)	(B)	(C)	(D)	(E)
	Number of Time Lags of $\tau^f_{i,t}$:				
	0	1	2	3	4
A. Competitive States Tax Variable					
$\tau^f_{i,t}$	1.070 (0.298)	-1.596 (0.493)	-1.538 (0.442)	-1.549 (0.419)	-1.620 (0.434)
$\tau^f_{i,t-1}$	------	0.907 (0.432)	0.617 (0.458)	0.640 (0.431)	0.699 (0.452)
$\tau^f_{i,t-2}$	------	------	0.262 (0.189)	0.004 (0.227)	-0.003 (0.235)
$\tau^f_{i,t-3}$	------	------	------	0.285 (0.257)	0.440 (0.364)
$\tau^f_{i,t-4}$	------	------	------	------	-0.176 (0.276)
α = Sum of Coefficients on the $\tau^f_{i,t}$'s	1.070 (0.298) [0.000]	-0.689 (0.164) [0.000]	-0.658 (0.169) [0.000]	-0.619 (0.181) [0.001]	-0.660 (0.185) [0.000]
B. Control Variables					
$\text{PREFERENCES}_{i,t-1}$	-0.005 (.001)	-0.003 (.001)	-0.003 (.001)	-0.003 (.001)	-0.003 (.001)
$\text{GDPGROWTH}_{i,t-1}$	0.004 (.006)	0.005 (.006)	0.005 (.006)	0.004 (.006)	0.004 (.006)
$\text{POPULATION}_{i,t}$	-0.010 (.002)	-0.009 (.002)	-0.010 (.002)	-0.009 (.002)	-0.009 (.002)
$\text{GDPGROWTH}^f_{i,t-1}$	-0.033 (.030)	-0.016 (.020)	-0.016 (.020)	-0.015 (.020)	-0.016 (.020)
$\text{POPULATION}^f_{i,t}$	-0.140 (.021)	-0.014 (.007)	-0.014 (.007)	-0.014 (.007)	-0.016 (.007)
Cross-Section Dependence	Yes	Yes	Yes	Yes	Yes
State Fixed Effects	Yes	Yes	Yes	Yes	Yes
C. Instrument Assessment					
p-value for test of overidentifying restrictions	0.780	0.790	0.848	0.849	0.830
Minimum eigenvalue statistic	23.328	12.489	15.386	16.163	14.568

Table Notes After Table 5

Table 2
Tax Policy (τ): Corporate Income Tax Rate ("Old and New Capital")
Common Correlated Effects Pooled (CCE) IV Estimator and
Various Time Lags of Tax Competition Variable

	(A)	(B)	(C)	(D)	(E)
	Number of Time Lags of $\tau^f_{i,t}$:				
	0	1	2	3	4
A. Competitive States Tax Variable					
$\tau^f_{i,t}$	0.756	0.373	0.289	0.269	0.288
	(0.078)	(0.426)	(0.384)	(0.345)	(0.453)
$\tau^f_{i,t-1}$	------	-0.686	-0.218	-0.233	-0.685
		(0.383)	(0.421)	(0.384)	(0.456)
$\tau^f_{i,t-2}$	------	------	-0.305	0.311	0.346
			(0.247)	(0.411)	(0.584)
$\tau^f_{i,t-3}$	------	------	------	-0.566	0.108
				(0.248)	(0.505)
$\tau^f_{i,t-4}$	------	------	------	------	-0.625
					(0.217)
α = Sum of Coefficients on the $\tau^f_{i,t}$'s	0.756	-0.313	-0.235	-0.220	-0.567
	(0.078)	(0.187)	(0.151)	(0.140)	(0.193)
	[0.000]	[0.095]	[0.120]	[0.116]	[0.003]
B. Control Variables					
$PREFERENCES_{i,t-1}$	-0.002	-0.002	-0.002	-0.002	-0.002
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
$GDPGROWTH_{i,t-1}$	-0.011	-0.010	-0.010	-0.009	-0.009
	(0.006)	(0.008)	(0.008)	(0.008)	(0.007)
$POPULATION_{i,t}$	-0.016	-0.013	-0.012	-0.012	-0.014
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
$GDPGROWTH^f_{i,t-1}$	0.013	0.014	0.016	0.010	0.020
	(0.010)	(0.019)	(0.018)	(0.017)	(0.023)
$POPULATION^f_{i,t}$	-0.012	-0.007	-0.004	0.000	-0.023
	(0.003)	(0.007)	(0.007)	(0.007)	(0.009)
Cross-Section Dependence	Yes	Yes	Yes	Yes	Yes
State Fixed Effects	Yes	Yes	Yes	Yes	Yes
C. Instrument Assessment					
p-value for test of overidentifying restrictions	0.275	0.289	0.231	0.208	0.263
Minimum eigenvalue statistic	117.817	21.065	22.336	23.760	20.891

Table Notes After Table 5

Table 3
Estimated Slope of Reaction Function For Each Tax Policy
(α = Sum of Coefficients on the $\tau^{f}_{i,t}$'s)
Various IV Estimators and Time Lags of Tax Competition Variable

	(A)	(B)	(C)	(D)	(E)
	Number of Time Lags of $\tau^{f}_{i,t}$:				
	0	1	2	3	4
A. Investment Tax Credit Rate					
"New Capital"					
Common Correlated Effects Pooled (CCE)	1.070	-0.689	-0.658	-0.619	-0.660
	(0.298)	(0.164)	(0.169)	(0.181)	(0.185)
	[0.000]	[0.000]	[0.000]	[0.001]	[0.000]
Two-way Fixed Effects (TFE)	6.874	-1.325	-1.421	-1.504	-1.662
	(2.177)	(0.274)	(0.340)	(0.345)	(0.447)
	[0.002]	[0.000]	[0.000]	[0.000]	[0.000]
One-way (state) fixed effects (NTFE)	1.543	0.440	0.436	0.423	0.416
	(0.150)	(0.093)	(0.094)	(0.098)	(0.116)
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
B. Corporate Income Tax Rate					
"Old and New Capital"					
Common Correlated Effects Pooled (CCE)	0.756	-0.313	-0.235	-0.220	-0.567
	(0.078)	(0.187)	(0.151)	(0.140)	(0.193)
	[0.000]	[0.095]	[0.120]	[0.116]	[0.003]
Two-way Fixed Effects (TFE)	1.433	1.479	1.404	1.354	1.422
	(0.141)	(1.133)	(1.086)	(1.030)	(1.054)
	[0.000]	[0.192]	[0.196]	[0.189]	[0.177]
One-way (state) fixed effects (NTFE)	0.970	1.039	0.988	0.902	0.839
	(0.043)	(0.311)	(0.302)	(0.216)	(0.183)
	[0.000]	[0.001]	[0.001]	[0.000]	[0.000]

Table Notes After Table 5

Table 4:
Estimated Slope of Reaction Function For Each Tax Variable
(α = Sum of Coefficients on the $\tau^{f}_{i,t}$ ’s)
Summary Table of Robustness Checks

Model	(A) ITC: One-way (State) Fixed Effects; NTFE	(B) ITC: Common Correlated Effects (CCE); 3 Time Lags Of $\tau^{f}_{i,t}$		(C) CIT: One-way (State) Fixed Effects; NTFE	(D) CIT: Common Correlated Effects (CCE); 3 Time Lags Of $\tau^{f}_{i,t}$
A. Baseline	1.543 (0.150) [0.000]	-0.619 (0.181) [0.001]		0.970 (0.043) [0.000]	-0.220 (0.140) [0.116]
B. Additional Controls					
1. Manufacturing Share Of State GDP Lagged One Year	1.777 (0.221) [0.000]	-1.147 (0.260) [0.000]		0.998 (0.052) [0.000]	-0.660 (0.218) [0.002]
2. Tax Variables					
- Sample Starting In 1977 New Baseline	1.922 (0.279) [0.000]	-1.096 (0.291) [0.000]		0.709 (0.270) [0.009]	-0.042 (0.232) [0.855]
- Control Variables Added	1.973 (0.261) [0.000]	-1.201 (0.292) [0.000]		0.711 (0.273) [0.009]	-0.137 (0.229) [0.550]
3. Government Expenditures Share Of State GDP Lagged One Year	3.795 (1.145) [0.001]	-0.680 (0.164) [0.000]		0.965 (0.063) [0.000]	-0.832 (0.198) [0.000]
4. Population Share 20-64 Years Old	1.728 (0.227) [0.000]	-1.936 (0.309) [0.000]		0.890 (0.197) [0.000]	-0.237 (0.175) [0.175]
5. Corporate Tax Revenue Share Of State GDP	2.083 (0.454) [0.000]	-0.482 (0.207) [0.020]		1.064 (0.083) [0.000]	-0.175 (0.116) [0.133]
C. Alternative Variable Definitions And Samples					
6. Spatial Weighting Matrix Population/Distance	0.478 (0.342) [0.161]	-0.351 (0.064) [0.000]		0.657 (0.104) [0.000]	-0.322 (0.126) [0.010]
7. Spatial Weighting Matrix Commodity Flows	0.729 (0.123) [0.000]	-0.252 (0.064) [0.000]		0.683 (0.103) [0.000]	-1.024 (0.302) [0.001]
8. Lengthened Sample 1965 to 2011	2.149 (0.365) [0.000]	-0.746 (0.117) [0.000]		0.967 (0.028) [0.000]	-0.843 (0.258) [0.001]

Table 4 (continued):
Estimated Slope of Reaction Function For Each Tax Variable
(α = Sum of Coefficients on the $\tau^{f}_{i,t}$'s)
Summary Table of Robustness Checks

Model	(A) ITC	(B) ITC		(C) CIT	(D) CIT
D. Alternative Specifications					
9. OLS	0.397 (0.091) [0.000]	-0.577 (0.154) [0.000]		0.689 (0.068) [0.000]	-0.206 (0.120) [0.085]
10. All Independent Variables Lagged One Period	1.543 (0.150) [0.000]	-1.069 (0.157) [0.000]		0.970 (0.043) [0.000]	-1.190 (0.291) [0.000]
11. Lagged Dependent Variable	3.132 (0.603) [0.000]	-0.814 (0.183) [0.000]		0.499 (0.196) [0.011]	-0.690 (0.289) [0.017]
12. Inefficient CCE	---------	-0.347 0.380 0.360		---------	-0.096 0.468 0.837

Table Notes After Table 5

Table 5
Estimated Slope of Reaction Function For Alternative Tax Policy Measures
(α = Sum of Coefficients on the $\tau^f_{i,t}$'s)
Various IV Estimators and Time Lags of Tax Competition Variable

	Number of Time Lags of $\tau^f_{i,t}$:				
	0	1	2	3	4
A. Tax Wedge On Capital					
Common Correlated Effects Pooled (CCE)	2.379	-1.062	-1.147	-1.241	-1.378
	(0.114)	(0.134)	(0.132)	(0.136)	(0.130)
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Two-way Fixed Effects (TFE)	-0.054	-1.161	-1.212	-1.309	-1.343
	(7.747)	(0.511)	(0.553)	(0.560)	(0.695)
	[0.994]	[0.023]	[0.028]	[0.019]	[0.054]
One-way (state) fixed effects	1.199	1.081	1.171	1.201	1.219
	(0.094)	(0.735)	(0.816)	(0.787)	(0.759)
	[0.000]	[0.141]	[0.151]	[0.127]	[0.108]
B. Average Corporate Tax Rate					
Common Correlated Effects Pooled (CCE)	0.948	-0.275	0.033	-0.037	-0.072
	(0.023)	(0.117)	(0.130)	(0.171)	(0.187)
	[0.000]	[0.019]	[0.802]	[0.826]	[0.702]
Two-way Fixed Effects (TFE)	2.424	0.906	1.006	1.005	0.989
	(0.113)	(0.522)	(0.417)	(0.507)	(0.515)
	[0.000]	[0.083]	[0.016]	[0.048]	[0.055]
One-way (state) fixed effects	0.976	1.147	1.167	1.197	1.233
	(0.086)	(0.228)	(0.265)	(0.320)	(0.338)
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
C. Capital Apportionment Weight					
Common Correlated Effects Pooled (CCE)	0.889	-1.697	-1.731	-1.709	-1.688
	(0.049)	(0.070)	(0.070)	(0.064)	(0.065)
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Two-way Fixed Effects (TFE)	2.265	-3.641	-3.745	-3.857	-3.997
	(1.287)	(0.223)	(0.220)	(0.244)	(0.240)
	[0.079]	[0.000]	[0.000]	[0.000]	[0.000]
One-way (state) fixed effects	0.735	0.506	0.528	0.553	0.588
	(0.264)	(0.063)	(0.065)	(0.067)	(0.070)
	[0.006]	[0.000]	[0.000]	[0.000]	[0.000]

Notes To The Tables:
Instrumental variable (IV) estimates are based on equation (10) and panel data for 48 states for the period 1965 to 2006. Given the maximum of four time lags, the effective sample is for the period 1969 to 2006. To enhance comparability across models, the 1969 to 2006 sample is used for all estimates. Some of the tables differ with respect to the tax variables appearing as dependent and independent variables. The foreign states tax variable ($\tau^{f}_{i,t-n}$, $n = 0,...,4$) is defined in equation (8) as the spatial lag of the home state tax variable, $\tau_{i,t}$. The competitive set of states is defined by all states other than state *i*, and the spatial lag weights are the inverse of the distance between the population centroids for state *i* and that of a foreign state, normalized to sum to unity. There are five control variables: $\text{PREFERENCES}_{i,t-1}$ captures the political preferences of the state, lagged one period to avoid endogeneity issues; $\text{GDPGROWTH}_{i,t-1}$ is the state GDP growth, lagged one period to avoid endogeneity issues; $\text{POPULATION}_{i,t}$ is the state population; $\text{GDPGROWTH}^{f}_{i,t-1}$ and $\text{POPULATION}^{f}_{i,t}$ are the spatial lags of $\text{GDPGROWTH}_{i,t-1}$ and $\text{POPULATION}_{i,t}$, respectively. The CCE estimator requires cross-section averages (CSA) of the dependent and independent variables as additional regressors; see Sections IV.B and IV.D for details. To account for the endogeneity of $\tau^{f}_{i,t}$, we project this variable against a set of instruments whose selection is discussed in Section IV.C. See Section III and Appendix C for further details about definitions and data sources for the model variables and instruments. Instrument validity is assessed in terms of the Hansen J statistic based on the overidentifying restrictions. The null hypothesis of instrument validity is assessed in terms of the p-values presented in Tables 1 and 2. A p-value greater than an arbitrary critical value (e.g., 0.10) implies that the null hypothesis is not rejected and that the instruments are not invalid. Instrument relevance is assessed in terms of the minimum eigenvalue statistic assessing the joint significance of the excluded instruments from the projection of $\tau^{f}_{i,t}$ on the included (i.e., control variables) and excluded instruments. The α parameter measures the slope of the reaction function and, per equation (9b), is the sum of the coefficients on the included $\tau^{f}_{i,t-n}$ variable(s). Standard errors for the CCE estimates are robust to heteroskedasticity and clustered by year (to allow for any residual spatial dependence in the error term).

Tax Competition Among U.S. States:
Racing to the Bottom or Riding on a Seesaw?

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Appendices

Appendix A: The Tax Reaction Function: An Explicit Derivation

This appendix contains a detailed development of our model of strategic competition and extracts implications for the tax reaction function – the equilibrium response of tax policy in a home (in-state) jurisdiction to tax policy in a foreign (out-of-state) jurisdiction. It is complementary to the discussion in Section II and Figure 5. We show that the slope of the reaction function can be positive ("racing to the bottom") or negative ("riding on a seesaw") and that the sign of this slope depends on the sign of one key parameter – the income elasticity of private goods relative to public goods. The sign of this elasticity is related to whether private goods as a whole are a necessary or luxury goods, a condition closely related to the validity of Wagner's Law.[1] The model developed in this section is useful for identifying the determinants of the slope of the reaction function, suggesting hypotheses, and interpreting the empirical results.

A. A Model Of Tax Competition

Our model of tax competition is based on six relations that describe the constraints faced by a government choosing business capital tax policy to maximize the utility of the representative domestic household. First, production in the home state is determined by a Cobb-Douglas function that depends on a mobile capital stock and a fixed factor of production, such as land or infrastructure (the Cobb-Douglas assumption is adopted for analytic convenience). The capital stock available for home production (K) is the sum of the capital stocks owned by home residents (k) and, given the mobility of capital, the capital stock owned by foreign residents but located in the home state (k^f).[2] We write the production function ($F[K]$) in the following intensive form relative to the fixed factor of production (note that brackets are used in this paper to identify arguments in functional relations),

$$y = F[K], \tag{A-1}$$

$$K \equiv k + k^f,$$

$$F'[K] > 0,\ F''[K] < 0.$$

[1] Wagner's Law states that the share of government spending (as a percentage of GDP) increases with aggregate income. It is named after the 19th century German economist, Adolph Wagner.

[2] If the state is a net capital exporter, $k^f < 0$. Without loss in generality, we analyze a capital importing state.

Second, as a result of capital mobility, the capital stock in a given state is sensitive to capital income tax rates prevailing in home and foreign states. Consequently, the capital stock in the home state depends negatively on the home capital tax rate (τ) and positively on the foreign capital tax rate (τ^f), as well as on a set of controls reflecting home and foreign demographic and economic variables (x_k and x_k^f , respectively),

$$k^f \;=\; K[\tau : \tau^f, x_k, x_k^f], \tag{A-2}$$

$$K_\tau[.] < 0, \;\; K_{\tau^f}[.] > 0.$$

This capital mobility function allows economic and demographic variables to affect home capital demand insofar as they impact production possibilities and the marginal product of capital. It proves convenient to assume that the derivatives with respect to the home and foreign capital tax rates are equal and opposite in sign ($K_\tau[.] = -K_{\tau^f}[.]$), though the qualitative results do not require this assumption.[3]

Equations (A-1) and (A-2) can be combined to generate a relation between production and the home and foreign tax rates,

$$y \;=\; F[K] \;=\; F\Big[K[\tau : \tau^f, x_k, x_k^f]\Big] \;=\; G\Big[\tau : \tau^f, x_k, x_k^f\Big], \tag{A-3}$$

$$G_\tau[.] < 0, \;\; G_{\tau^f}[.] > 0.$$

The derivative, $G_{\tau^f}[.] > 0$, represents the incremental home production from a tax-induced flow of capital from the foreign state to the home state.

Third, we link net income to expenditures by means of GDP accounting relations. Net income available for domestic expenditures is measured by gross income (production) less the return on capital assets (r^f) owned by foreign residents but located in the home state. Net income is set equal to domestic expenditures, defined as the sum of public goods (g) and private goods (c),

$$y - r^f \;=\; g + c\,. \tag{A-4}$$

Fourth, the government budget constraint (stated per unit of the fixed factor) equates public goods expenditure to two sources of tax revenue. For the purposes of this study, the most

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[3] While equation (A-2) and its partial derivatives are consistent with the implications from the standard constraint equating net-of-tax returns across jurisdictions, our formulation allows for the possibility that, owing to a variety of frictions (discussed in the literature on the Lucas Paradox (Lucas, *American Economic* Review, 1980), the net-of-tax returns on capital may differ. See Appendix B.1 for analytic details about the capital mobility function.

important tax is an origin-based tax on capital income. This tax is defined as the product of the capital income tax rate (τ) and capital income, the latter defined as the marginal product of capital ($F'[K]$) multiplied by the capital stock located in the home state. The second source of revenue is a sales tax defined as the product of the sales tax rate (s) and income. This tax rate will be held constant in this analysis. The government budget constraint becomes,

$$g = \tau \; F'[K] \, K + s\,y = \tau \, \pi \, y + s\,y = (\tau \, \pi + s) \, y.^{4} \tag{A-5}$$

Fifth, capital imported from abroad is paid a return equal to the marginal product of capital multiplied by the amount of foreign capital located in the home state. As a result of the Cobb-Douglas production function, the return on imported capital is a fixed share (π^f) of output,

$$r^f = F'[K] \, k^f = \pi^f \, y, \tag{A-6}$$

$$\pi^f < \pi .$$

Equations (A-4), (A-5), and (A-6) can be combined to generate a relation between the mix of public and private goods ($g/c \equiv \zeta$) and the capital tax rate. We multiply and divide the two terms on the right-side of equation (A-4) by g, use equations (A-5) and (A-6) to eliminate g and r^f , respectively, and rearrange the resulting equation to obtain the following equation,

$$\zeta \equiv g/c = \frac{(\tau \pi + s)}{(1-\pi^f) - (\tau \pi + s)} \equiv S[\tau], \tag{A-7}$$

$$S_\tau[.] > 0 .$$

This condition shows that an increase in the share of output devoted to public goods requires an increase in the capital tax rate. Equation (A-7) is the supply curve presented in Figure 1 ζ to τ .

The sixth and final equation is the utility function that represents preferences for public and private goods. This function and its implications for ζ were discussed in Section II.B, and is repeated here for convenience,

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[4] A wage tax at rate τ_{wage} could enter the model by adding ($\tau_{wage}\,(1-\pi)\,y$) to the right side of equation (A-5).

$$\zeta \equiv g/c = \xi\, p\left(y(1-\pi^f)\right)^{\eta_{\zeta,y}} = \xi\, p\left(G\left[\tau:\tau^f, x_k, x_k^f\right](1-\pi^f)\right)^{\eta_{\zeta,y}} = D\left[\tau:\tau^f, \eta_{\zeta,y}\right], \quad \text{(A-8a)}$$

$$\xi \equiv \left(\xi_g\theta_g / \xi_c\theta_c\right) > 0, \quad \text{(A-8b)}$$

$$p \equiv \left(p_c^{(\theta_c+1)} / p_g^{(\theta_g+1)}\right) > 0, \quad \text{(A-8c)}$$

$$\eta_{\zeta,y} \equiv \theta_g - \theta_c >=< 0. \quad \text{(A-8d)}$$

where, in equation (A-8a), we have substituted for y with equation (A-3). Equation (A-8a) is the demand curve presented in Figure 1 relating ζ to τ, τ^f, and $\eta_{\zeta,y}$.

The above model serves as a vehicle for studying the properties of the tax reaction function. The model is summarized by equations (A-3), (A-7), and (A-8). Substituting the first two equations into the third equation, we determine the optimal capital tax rate, τ^*, and its relation to the foreign capital tax rate,

$$g/c = \zeta[y(1-\pi^f) : x_\zeta], \quad \text{(A-9)}$$

$$0 = \zeta\left[G[\tau^*:\tau^f, x_k, x_k^f](1-\pi^f) : x_\zeta\right] - S[\tau],$$

$$0 = \Phi[\tau^*:\tau^f, x].$$

$$x \equiv \{x_k, x_k^f, x_\zeta, \pi^f, \pi, s\}$$

Appendix B.2 verifies the existence of τ^*.

Appendix B: Additional Analytic Results For The Strategic Tax Competition Model

Appendix B.1; Properties Of The Capital Mobility Function

This appendix provides some analytic details concerning the properties of the capital mobility function (equation (A-2)) used in this paper. This function allows for the possibility that, owing to a variety of frictions, the net-of-tax returns on capital may differ across jurisdictions. This appendix demonstrates that the capital mobility function and its partial derivatives are consistent with the implications from the standard constraint equating net-of-tax returns across jurisdictions.

Equation (A-2) is reproduced here as follows,

$$k^f = K[\tau : \tau^f, x_k, x_k^f], \tag{B.1-1}$$

$$K_\tau[.] < 0, \;\; K_{\tau^f}[.] > 0.$$

where k^f is the capital stock owned by foreign residents but located in the home state. Without loss of generality, we assume that the home state is a capital importer.

The purpose of this exercise is to derive the properties of this function from a generalized equation relating net-of-tax returns in the home and foreign jurisdictions, which is written as follows,

$$(1-\tau)\, F'[K] + \Delta = (1-\tau^f)\, \Im'[K^f], \tag{B.1-2}$$

where Δ is a wedge that represents a variety of frictions preventing equalization of net-of-tax returns across jurisdictions, $F'[K]$ and $\Im'[K^f]$ are the marginal products of capital for the home and foreign jurisdictions, respectively. The production functions for both jurisdictions are subject to the Inada conditions (which guarantee that equation (B.1-2) will hold for some capital allocation). We assume that there is a fixed amount of capital ($\bar{K}$) that is allocated between the home and foreign jurisdictions,

$$K = \bar{K} + k^f, \tag{B.1-3a}$$

$$K^f = \bar{K}^f - k^f, \tag{B.1-3b}$$

where $\bar{K}$ and $\bar{K}^f$ are the initial amounts of capital in the home and foreign states, respectively. Substituting equation (B.1-3) into (B.1-2), differentiating the resulting expression by k^f, τ, and τ^f, noting that $dK = dk^f$, and rearranging, we obtain the following derivatives,

$$K_{\tau}[.] \equiv \frac{dK}{d\tau} = \frac{F'[.]}{(1-\tau)\, F''[.] + (1-\tau^f)\, \Im''[.]} < 0, \tag{B.1-4a}$$

$$K_{\tau^f}[.] \equiv \frac{dK}{d\tau^f} = \frac{-\Im'[.]}{(1-\tau)\, F''[.] + (1-\tau^f)\, \Im''[.]} > 0, \tag{B.1-4b}$$

where we have assumed that the production functions exhibit diminishing marginal products ($F''[.] < 0, \Im''[.] < 0$). If the production functions are identical across jurisdictions, then $K_{\tau}[.] = -K_{\tau^f}[.]$.

Appendix B.2: The Existence Of An Equilibrium Tax Rate And Its Relation To The Pre-Tax Capital Income Share

This appendix provides some analytic details concerning the existence of an equilibrium tax rate (τ^*) in the indirect utility model and its relation to the pre-tax capital income share and the rate of sales taxation. We analyze a symmetric equilibrium between home and foreign jurisdictions. We begin with the three relations that summarize the content of the theoretical model presented in Section II.A,

$$y = F[K] = F\left[K[\tau:\tau^f, x_k, x_k^f]\right] = G\left[\tau:\tau^f, x_k, x_k^f\right], \tag{B.2-1}$$

$$G_\tau[.] < 0, \quad G_{\tau^f}[.] > 0.$$

$$\zeta \equiv g/c = \frac{(\tau\pi + s)}{(1-\pi^f) - (\tau\pi + s)} \equiv S[\tau], \tag{B.2-2}$$

$$S_\tau[.] > 0.$$

$$\zeta \equiv g/c = \xi\, p\left(y(1-\pi^f)\right)^{\eta_{\zeta,y}} = \zeta\left[y : \xi, p, \pi^f\right] = D[\tau], \tag{B.2-3a}$$

$$\xi \equiv \left(\xi_g\theta_g / \xi_c\theta_c\right) > 0, \tag{B.2-3b}$$

$$p \equiv \left(p_c^{(\theta_c+1)} / p_g^{(\theta_g+1)}\right) > 0, \tag{B.2-3c}$$

$$\eta_{\zeta,y} \equiv \theta_g - \theta_c >=< 0. \tag{B.2-3d}$$

where equation (B.2-1) is equation (A-3) representing the production function and the mobile capital stock, equation (B.2-2) is equation (A-7) representing the aggregate and government budget constraints, and equation (B.2-3) is equation (A-9) representing optimized choices of public and private goods.

Under the symmetry assumption, no capital flows between jurisdictions because the tax rates are equal. Thus, equation (B.2-1) implies that the level of output in each country is constant, $y = \overline{y}$. Substituting this constant into equation (B.2-3) and eliminating ζ with equation (B.2-2), we obtain the following solution for τ^*

$$\frac{\left(\tau^{*}\pi+s\right)}{\left(1-\pi^{f}\right)-\left(\tau^{*}\pi+s\right)} = \zeta\left[\bar{y} : \xi,\ p,\ \pi^{f}\right],$$

$$\rightarrow \tag{B.2-4}$$

$$\tau^{*} = \frac{\zeta(1-\pi^{f})-s(1+\zeta)}{\pi(1+\zeta)},$$

Since representative estimates of ζ, s, and π are 0.270, 0.025, and 0.33, respectively, $\tau^{*}>0$ is ensured because the maximum value of π^{f} is π (the capital income share).

Moreover, equation (B.2-4) establishes that there is a negative relation between τ^{*} and the pre-tax capital income share (π), as well as the rate of sales taxation (s).

Appendix B.3: Comparing the CES Direct and Addilog Indirect Utility Functions

The addilog indirect utility function that is the basis for our theoretical model is used less frequently than a CES direct utility function. (Note that a Cobb-Douglas direct utility function is a special case of the CES.) This appendix compares the implications of both utility functions for the relative public goods ratio, ζ, and shows that the CES direct utility function is less general than the addilog indirect utility function.

The CES direct utility function is written as follows,

$$U[c,g] = \left\{(\kappa\, g)^{-\rho} + ((1-\kappa)\, c)^{-\rho}\right\}^{-(1/\rho)}, \tag{B.3-1a}$$

$$\rho \equiv (1-\sigma)/\sigma \tag{B.3-1b}$$

where κ is the CES distribution parameter, ρ the substitution parameter, and σ the elasticity of substitution between g and c. The addilog indirect utility function was presented in Section II, and it is reproduced here,

$$V[y] = \xi_g \left(y/p_g\right)^{\theta_g} + \xi_c \left(y/p_c\right)^{\theta_c}. \tag{B.3-2}$$

where $\theta_c, \theta_g, \xi_c$, and ξ_g are positive parameters representing preferences. (For notational simplicity and without loss in generality, we have set $\pi^f = 0$.)

Each utility function generates demand functions for c and g based on optimizing behavior subject to the following budget constraint,

$$y = p_g\, g + p_c\, c, \tag{B.3-3}$$

where p_g and p_c are the prices for g and c, respectively. The demand functions for g and c following from the CES direct utility function are as follows,

$$g = \frac{\kappa^{\sigma}\, p_g^{(1-\sigma)}}{\kappa^{\sigma}\, p_g^{(1-\sigma)} + (1-\kappa)^{\sigma}\, p_c^{(1-\sigma)}} * \frac{y}{p_g}, \tag{B.3-4a}$$

$$c = \frac{(1-\kappa)^{\sigma}\, p_c^{(1-\sigma)}}{\kappa^{\sigma}\, p_g^{(1-\sigma)} + (1-\kappa)^{\sigma}\, p_c^{(1-\sigma)}} * \frac{y}{p_c}, \tag{B.3-4b}$$

These two demand functions imply the following relation for the relative demand for public goods, $\zeta \equiv g/c$,

$$\zeta^{CES} = \left\{\frac{\kappa}{(1-\kappa)}\right\}^{\sigma} \left\{\frac{p_c}{p_g}\right\}^{\sigma}. \tag{B.3-5}$$

As discussed in Section II, a key property of the addilog indirect utility function is that the "ratios between any two expenditures have a constant elasticity with respect to total expenditure" (Houthakker, 1960, p. 253). Relying on Roy's identity to generate the demand functions for c and g, we obtain after some additional manipulation the following equation for the relative demand for public goods (Houthakker, 1960, equation (30)),

$$\zeta^{Addilog} = \xi \; p \; y^{\eta_{\zeta,y}}, \tag{B.3-6a}$$

$$\xi \equiv \left(\xi_g \theta_g / \xi_c \theta_c\right) > 0, \tag{B.3-6b}$$

$$p \equiv \left(p_c^{(\theta_c+1)} / p_g^{(\theta_g+1)}\right) > 0, \tag{B.3-6c}$$

$$\eta_{\zeta,y} \equiv \theta_g - \theta_c >=< 0. \tag{B.3-6d}$$

A comparison of equations (B.3-5) and (B.3-6) reveals that the addilog indirect utility function yields a more general model of the determinants of the relative demand for public goods. The following restrictions on equation (B.3-6) yield equation (B.3-5) for any values of σ and κ,

$$\theta_g = \theta_c = \sigma - 1, \tag{B.3-7a}$$

$$\xi \equiv \xi_g / \xi_c = \{\kappa / (1-\kappa)\}^{\sigma}. \tag{B.3-7b}$$

Apart from these restrictions, the addilog model generates a model that is more general and, most importantly for the study of tax competition, allows for income to have a direct impact on the relative demand for public goods.

Appendix B.4: Tax Competition In A Direct Utility Model

This appendix analyzes the tax competition model developed in Section II with the indirect utility function (equation (8)) replaced by the following direct utility function defined in terms of c and g,

$$U[g,c] = \Upsilon\, c^{-\kappa} g^{\tilde{\psi}}. \tag{B.4-1}$$

It proves convenient to rewrite equation (B.4-1) in terms of the private/public goods mix variable,

$$U[\zeta,c] = \Upsilon\, \zeta^{\kappa} g^{\psi} \qquad \psi \equiv \tilde{\psi} - \kappa. \tag{B.4-2}$$

The optimization problem facing policymakers is to choose τ in order to maximize equation (B.4-2) constrained by equations (A-3), (A-5), and (A-7) reproduced here in abbreviated form for convenience,

$$y = F[K] = F\left[K[\tau : \tau^{f}, x_{k}, x_{k}^{f}]\right] = G\left[\tau : \tau^{f}, x_{k}, x_{k}^{f}\right], \tag{B.4-3}$$

$$G_{\tau}[.] < 0, \;\; G_{\tau^{f}}[.] > 0.$$

$$g = \tau\; F'[K]\, K + s\, y = \tau\, \pi\, y + s\, y = \left(\tau\, \pi + s\right) y. \tag{B.4-4}$$

$$\zeta \equiv g/c = \frac{\left(\tau\pi + s\right)}{\left(1-\pi^{f}\right) - \left(\tau\pi + s\right)} \equiv S[\tau], \tag{B.4-5}$$

$$S_{\tau}[.] > 0.$$

To simplify the analysis, we have assumed that capital income taxation is the only sources of revenue in equation (B.4-4) (i.e., setting s = 0 in equation (A-5)). Substituting equation (B.4-3) into equation (B.4-4) to eliminate y, and restating ζ and c in equation (B.4-2) in terms of τ with equation (B.4-5) and the modified (B.4-4), respectively, the optimization problem can stated solely in terms of τ,

$$U[\tau] = \Upsilon\, \left\{S[\tau]\right\}^{\kappa} \left\{\tau\pi G[\tau]\right\}^{\psi} \tag{B.4-6}$$

Differentiating equation (B.4-6) with respect to τ and rearranging, we obtain the following equation determining the optimal τ implicitly,

$$\tau^* = \left(1 - \frac{\kappa / \psi}{(1 - \Gamma[\tau^* : \tau^f])}\right) \left(\frac{(1 - \pi^f)}{\pi}\right). \tag{B.4-7}$$

where Γ is the elasticity of output with respect to the capital tax rate (reflecting both the sensitivity of capital flows to the capital tax rate and output to the capital stock; see equation (3b) for further details). Assume that Γ is constant. In this case, equation (B.4-7) has the reasonable properties that the optimal capital income tax rate depends (1) negatively on the relative utility weight on private goods (κ / ψ), (2) negatively on the share of capital income (thus requiring a lower capital tax rate to collect a given amount of revenue), and (3) negatively on Γ (reflecting the amount of capital outflow for a given change in τ).

Differentiating equation (B.4-7) with respect to τ and τ^f with the chain rule and rearranging yields the following reaction function,

$$\frac{d\tau}{d\tau^f} = \frac{\delta^* \Gamma'}{\left(1 + \delta^* \Gamma'\right)} , \tag{B.4-8a}$$

$$\delta \equiv \left(\kappa / \psi\right)\left((1 - \pi^f) / \pi\right)\left(1 - \Gamma[.]\right)^{-2} > 0, \tag{B.4-8b}$$

$$\Gamma' \equiv d\Gamma / d\tau . \tag{B.4-8c}$$

Relative to our preferred reaction function derived from an indirect utility function, equation (B.4-8) is restrictive because its sign depends on the direction of change in an elasticity, a derivative that is unrelated to traditional economic mechanisms and intuition. Note that, if the production and capital flow functions constituting Γ have constant elasticities, then $\Gamma' = 0$ and $d\tau / d\tau^f > 0$. Most importantly, the direct utility model does not allow for the possibility that the public/private good mix is sensitive to income. Such a restriction is relaxed in the indirect utility model and proves very important in understanding the slope of the reaction function.

Appendix C: Variable Definitions and Data Sources[5]

This appendix describes the construction of and data sources for the variables used in this study:

1. ACT: Average Corporate Tax Rate
2. CAW: Capital Apportionment Weight
3. CIT: Corporate Income Tax Rate
4. EXPS: State government expenditures share of state GDP
5. GDP (and GDPGROWTH): State Gross Domestic Product (and its growth rate)
6. ITC: Investment Tax Credit Rate
7. MFGSHR: Manufacturing share of state GDP
8. PERS: Personal Income Tax Rate
9. PREFERENCES: Voter Preferences
10. POPULATION (and POP20-64): Total Population (and population 20-64 years old)
11. TAXREV: Corporate tax revenue share of state GDP
12. TD: Tax Depreciation
13. TWC: Tax wedge on capital
14. $\omega_{i,j}$: Spatial Lag Weights
15. Legend

The series are for the 48 contiguous states (indexed by subscript s) for the period 1963 to 2006 (indexed by subscript *t*), unless otherwise noted.[6] Each of the above series is described in a separate section. The general organizing principle for each section is to first define each of the series mentioned above and then discuss its components. For each component, general issues concerning the construction of the series (if pertinent) and then data sources are discussed. Section 11 contains a Legend with abbreviations and sources.

[5] In describing the raw data, we have taken some of the text in this data appendix directly from government publications.

[6] The most notable exception is that the Annual Survey of Manufacturers was not conducted from 1979 to 1981.

1. ACT: Average Corporate Tax Rate

The average corporate tax rate is measured as follows,

$$ACT_{i,t} = REV_{i,t}^{CIT} \Big/ GOS_{i,t} ,$$

where $GOS_{i,t}$ is state private gross operating surplus and $REV_{i,t}^{CIT}$ is state government revenues from the corporate income tax.

Gross operating surplus data come from REA, and state tax revenues data comes from STC.

2. CAW: Capital Apportionment Weight

The capital apportionment weight (CAW) is the weight that the state assigns to capital (property) in its formula apportioning income among the multiple states in which firms generate taxable income. The apportionment formula is always a weighted average of the company's sales, payroll, and property (with zero weights allowed). However, the weights vary by state. In practice, the payroll and property weights are always equal, at least for the states and years in our sample, so that knowing one of the three weights for a state reveals the other two.

We construct data from 1963 – 2006 on the factor apportionment weights for each of the 48 contiguous states. We use a number of different sources. OMER provides information on the year in which each state first deviated from the traditional three-factor, equal weighting formula. Kelly Edmiston kindly provided data on apportionment weights for years 1997 and 2001 used in CESW. John Deskins kindly provided data panel data for 1985-2003 used in BDF. Lastly, we were able to obtain weights for various years from STH.

3. CIT: Corporate Income Tax Rate

The effective corporate income tax rate at the state level ($\tau_{i,t}^{E,S}$) is lower than the legislated (or statutory) corporate income tax rate ($\tau_{t}^{L,S}$) due to the deductibility (in some states) against state taxable income of taxes paid to the federal government.[7] Some states allow full deductibility of federal corporate income taxes from state taxable income; Iowa and Missouri allow only 50% deductibility; and some states allow no deductibility at all. The deductibility provision in state tax codes is represented by $\upsilon_{i,t} = \{1.0, 0.5, 0.0\}$, and the provisional effective corporate income tax rate at the state level ($\tau_{i,t}^{\#,E,S}$) is as follows,

$$\tau_{i,t}^{\#,E,S} = \tau_{t}^{L,S}\left(1 - \upsilon_{i,t}\tau_{i,t}^{\#,E,F}\right).$$

The effect of federal income tax deductibility is represented by the provisional *effective* corporate income tax rate at the federal level ($\tau_{i,t}^{\#,E,F}$, defined below).

The $\tau_{i,t}^{L,S}$ and $\upsilon_{i,t}$ series are obtained from several sources. For recent years, data are obtained primarily from various issues of BOTS and STH, as well as actual state tax forms. Data for earlier years are obtained from various issues of BOTS and SFFF. Additional information has been provided by TAXFDN. Many states have multiple legislated tax rates that increase stepwise with taxable income; we measure $\tau_{i,t}^{L,S}$ with the marginal legislated tax rate for the highest income bracket.

The effective corporate income tax rate at the federal level is lower than the legislated corporate income tax rate ($\tau_{t}^{L,F}$) due to the deductibility against federal taxable income of taxes paid to the state. The provisional effective corporate income tax rate at the federal level is as follows,

$$\tau_{i,t}^{\#,E,F} = \tau_{t}^{L,F}\left(1 - \tau_{i,t}^{\#,E,S}\right)$$

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[7] In "corporate income" taxes we also include Texas' "franchise" tax, which has a very similar tax base as the traditional corporate income tax base.

The effect of state income tax deductibility is represented by the *effective* corporate income tax rate at the state level. The $\tau_t^{L,F}$ series is obtained from GRAVELLE, Table 2.1. Our database presents $\tau_t^{L,F}$ in percentage points.

It has not generally been recognized that, owing to deductibility of taxes paid to another level of government, the effective corporate income tax rates at the state and federal levels are functionally related to each other. As shown in the above equations, these interrelationships yield two equations in two unknowns, and thus can be solved for the effective corporate income tax rates at the state and federal levels, respectively, as follows,

$$\tau_{i,t}^{E,S} = \tau_{i,t}^{L,S}\left[1-\upsilon_{i,t}\tau_t^{L,F}\right] \Big/ \left[1-\upsilon_{i,t}\tau_{i,t}^{L,S}\tau_t^{L,F}\right],$$
$$\tau_{i,t}^{E,F} = \tau_t^{L,F}\left[1-\tau_{i,t}^{L,S}\right] \Big/ \left[1-\upsilon_{i,t}\tau_{i,t}^{L,S}\tau_t^{L,F}\right].$$

The overall corporate income tax rate is the sum of $\tau_{i,t}^{E,S}$ and $\tau_{i,t}^{E,F}$. In the limiting case where federal corporate income taxes are not deductible against state taxable income ($\upsilon_{i,t} = 0$), this sum reduces to the more frequently used formula, $\tau_{i,t}^{L,S} + \left(1-\tau_{i,t}^{L,S}\right)\tau_t^{L,F}$.

4. EXPS: State Government Expenditures As A Share Of State GDP

The numerator comes from SGF and the denominator comes from REA. Both are measured in nominal dollars.

5. GDP: State Gross Domestic Product

Data on real state gross domestic product (GDP) and its growth rate (GDPGROWTH) come from REA.

6. ITC: Investment Tax Credit Rate

The state investment tax credit is a credit against state corporate income tax liabilities. We focus on investment tax credits that are permanent. In general, the effective amount of the investment tax credit is simply the legislated investment tax credit rate ($ITC_{i,t}^{L,S}$) multiplied by the value of capital expenditures put into place within the state in a tax year. The effective rate is lower than the legislated rate in a handful of states for two reasons. First, five states (Connecticut, Idaho, Maine, North Carolina, and Ohio) permit the state investment tax credit to be applied only to equipment. Since equipment investment is approximately 85% of ASM total national investment, we multiply $ITC_{i,t}^{L,S}$ by 0.85 for these five states. Second, states generally require basis adjustments deducting the amount of the credit from the asset basis for depreciation purposes; this adjustment is considered in the subsection on the Present Value of Tax Depreciation Allowances.

We extend the 1963-2004 state panel data on $ITC_{i,t}^{L,S}$ from Chirinko and Wilson (2008) through 2006. The original and extended data are obtained directly from states' online corporate tax forms and instructions. For most states with an investment tax credit, both current and historical credit rates are provided in the current year instructions (since companies applying for a credit based on some past year's investment apply that year's credit rate rather than the current rate). In those few cases where some or all historical rates were missing from the online forms and instructions, the missing rates are obtained via direct communication with the state's department of taxation. In some states, the legislated investment tax credit rate varies by the level of capital expenditures; we use the legislated credit rate for the highest tier of capital expenditures.

7. MFGSHR: Manufacturing State GDP As A Share Of Total State GDP

The numerator and denominator come from REA. Both are measured in nominal dollars.

8. PERS: Personal Income Tax Rate

The personal income tax rate is measured by the marginal tax rate for the median household computed from the NBER TaxSim simulator. TaxSim generates the marginal state tax rate for each state-year for a hypothetical taxpayer who files jointly, has no dependents, and has household income equal to the 50th percentile nationally for that year.

9. PREFERENCES: Voter Preferences

Voter preferences are measured by political outcomes. Specifically, we measure the following two political outcomes as indicator variables:

(a) the governor is Republican (R). (The complementary class of politicians is Democrat (D) or Independent (I). An informal examination of the political landscape suggests that Independents tend to be more closely aligned with the Democratic Party. We thus treat D or I politicians as belonging to the same class, DI);

(b) the majority of both houses of the legislature are R;

The PREFERENCES variable takes on one of three values:

0 if the governor and the majority of both houses of the legislature are not R;

1/2 if the governor is R but the majority of both houses of the legislature are not R or if the governor is not R but the majority of both houses of the legislature are R;

1 if the governor and the majority of both houses of the legislature are R.

Data for these political variables come from the Statistical Abstract of the United States (U.S. Census Bureau (Various Years)).

10. POPULATION (And POP20-64): Total Population (And Population 20-64 Years Old)

Data on total population and population aged 20-64 years old are obtained from CENSUS.

11. TAXREV: Corporate Tax Revenue As A Share Of State GDP

The numerator comes from SGF and the denominator comes from REA. Both are measured in nominal dollars.

12. TD: Tax Depreciation

Tax depreciation allowances accrue over the useful life of the asset. We have assumed that the present value of tax depreciation allowances, $TD_{i,t}$, is 0.70 for all s and t. We assume a slightly lower value than the average across asset types and years reported in GRAVELLE to adjust for the basis reduction by the amount of investment tax credits taken.

13. TWC: Tax Wedge on Capital

The price of capital (tax-adjusted) is defined as the product of three objects reflecting the purchase price of the capital good, the opportunity costs of holding depreciating capital, and taxes. This latter term comprises tax credits, tax deductions, and the tax rate on income, and we refer to these tax terms (less 1.0) as the tax wedge on capital,

$$TWC_{i,t} = \frac{1.0 - ITC_{i,t} - CIT_{i,t} * TD}{1 - CIT_{i,t}} - 1.0 \ .$$

In this paper, we define $TWC_{i,t}$ only in terms of state tax variables.

Note that the user cost of capital, which was introduced by JORGENSON-1 in 1963 and extended by, among others, HALL-JORGENSON, GRAVELLE, JORGENSON-YUN, and KING-FULLERTON, equals the price of capital divided by the price of output.

14. $\omega_{i,j}$: Spatial Lag Weights

The spatial lag weights in our baseline specifications are measured by the inverse of the distance between state population centroids (data are from CENSUS). In supplemental specifications, we also use spatial weights based oncommodity trade flows (data are from TRANSPORT) and spatial weights based on population divided by distance. The population data are for the year 2000 and come from CENSUS. All spatial weighting matrices are row-normalized.

15. Legend

ASM: CENSUS, *Annual Survey of Manufactures, Complete Volume* (Various Years).

ASM-GAS: CENSUS, *Annual Survey of Manufacturers, Geographic Area Statistics* (Various Years). Publications for the years 1994 to 2004 (except 1997 and 2002) are available online. These data are published on an establishment basis. The data are obtained from electronic or paper documents depending on the time period: 2004 (Census website); 2003 to 1972 (CD's purchased from Census); 1971 to 1963 (paper copies). URL: http://www.census.gov/mcd/asm-as3.html.

ASM-SIGI: CENSUS, *Annual Survey of Manufacturers, Statistics for Industry Groups and Industries* (1996). URL: http://www.census.gov/mcd/asm-as1.html.

BDF: Bruce, Donald, Deskins, John, and Fox, William F., "On The Extent, Growth, and Efficiency Consequences of State Business Tax Planning," mimeo, University of Tennessee, 2005.

BOTS: The Council of State Governments, *The Book of the States* (The Council of State Governments : Lexington, Kentucky, Various Issues).

CBP: CENSUS, *County Business Patterns.* URL: http://www.census.gov/epcd/cbp/download/cbpdownload.html.

CENSUS: Bureau of the Census, U.S. Department of Commerce. URL: http://www.census.gov.

CESW: Cornia, Gary; Edmiston, Kelly; Sjoquist, David L.; and Wallace, Sally, "The Disappearing State Corporate Income Tax," *National Tax Journal* 58 (March 2005), 115-138.

FIXED: BEA, *Standard Fixed Asset Tables.* URL: http://www.bea.gov/bea/dn/FA2004/SelectTable.asp.

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OMER: Omer, Thomas C., and Shelley, Marjorie K., "Competitive, Political, and Economic Factors Influencing State Tax Policy Changes," *Journal of the American Tax Association*, 26 (2004), 103-126.

REA: Bureau of Economic Analysis, *Regional Economic Accounts* URL: http://www.bea.gov/regional.

SGF: CENSUS, Survey of State Government Finances (SGF), various years. https://www.census.gov/govs/state/.

SFFF: American Council on Intergovernmental Affairs, *Significant Features of Fiscal Federalism* (Washington, DC: American Council on Intergovernmental Affairs, Various Issues). URL (e.g., 1987): http://www.library.unt.edu/gpo/ACIR/SFFF/SFFF-1988-Vol-1.pdf.

STC CENSUS, State Government Tax Collections report, various years. URL: http://www.census.gov/govs/www/statetax.html.

STH: Commerce Clearing House, *State Tax Handbook* (Chicago: Commerce Clearing House, Various Issues).

TAXFDN: Tax Foundation web site. URL: http://www.taxfoundation.org.

TRANSPORT: The U.S. Bureau of Transportation Statistics, *1997 Survey of Commodity Flows*.

Appendix D: A Distributed Lag Reaction Function

This appendix combines a static tax reaction function with a partial adjustment model to derive the distributed lag reaction function that generates the benchmark results in this paper.

The flow of capital among states may occur gradually over several years, and hence the observed τ_t will differ from the desired home state capital income tax rate, $\tau_t^{\#}$. To allow for the gradual response of τ_t, we adopt the following partial adjustment model,

$$\tau_t = \lambda\left(\tau_t^{\#} - \tau_{t-1}\right) + \tau_{t-1} + v_t, \tag{D-1}$$

where λ is a parameter determining how much of the discrepancy between the long-run and lagged τ's will be eliminated in period t, and v_t is a stochastic shock. The *i* subscripts have been omitted for convenience. Lagging equation (D-1) one period and successively substituting the lagged equations into equation (D-1) yields the following equation,

$$\tau_t = \lambda \sum_{j=0}^{J} (1-\lambda)^j \tau_{t-j}^{\#} + \sum_{j=0}^{J} (1-\lambda)^j v_{t-j} + (1-\lambda)^{(J+1)} \tau_{t-J-1}. \tag{D-2}$$

As $J \to \infty$, the last term vanishes. We use the static relation (equation (7)) to define $\tau_t^{\#}$,

$$\tau_t^{\#} = \alpha \tau_t^f + \beta x_t + u_t. \tag{D-3}$$

Substituting equation (D-3) into (D-2) and rearranging, we obtain the following distributed lag model,

$$\tau_t = \sum_{j=0}^{\infty} \tilde{\alpha}_j \tau_{t-j}^f + \sum_{j=0}^{\infty} \tilde{\beta}_j x_{t-j} + w_t, \tag{D-4}$$

$$\tilde{\alpha}_j \equiv \lambda \alpha (1-\lambda)^j,$$

$$\tilde{\beta}_j \equiv \lambda \beta (1-\lambda)^j,$$

$$w_t \equiv \sum_{j=0}^{\infty} (1-\lambda)^j \left(v_{t-j} + \lambda u_{t-j}\right),$$

$$\sum_{j=0}^{\infty} \tilde{\alpha}_j = \lambda \alpha \sum_{j=0}^{\infty} (1-\lambda)^j = \alpha.$$

As shown on the last line of Equation (D-4), the estimated coefficients on the τ_{t-j}^f's sum to α, the slope of the reaction function that is the prime focus of this paper.

Equation (D-4) is the basis for our estimation, which relies on a less general form of this equation in three dimensions. First, the distributed lags are truncated at no more than four periods. Lagged dependent variables allow us to capture the effects of lags further back in time, and this model is discussed in Appendix F.

Second, in order to conserve degrees of freedom, we lag the x variables only one period. An implication of equation (D-4) is that the composite error term will be correlated with all of the τ^f_{t-j}'s, not just τ^f_t. We explore the impact of this potential correlation on the coefficients of interest by instrumenting the lagged foreign tax rate variables with lags of our preferred instrument set (i.e., for a given n, $\tau^f_{i,t-n}$ is instrumented by $z^*_{\tau,i,t-n}$ for n=1,4). (We estimate the time fixed effects model because estimation of the CCE model would be computationally demanding with this expanded number of instruments.) Standard errors increase sharply and do not permit us to make any meaningful inferences. This result is traceable to a small amount of incremental information in $z^*_{\tau,i,t-n}$ relative to $z^*_{\tau,i,t}$. The eigenvalue for assessing instrument relevance is less than one for each model (i.e., n=1, 2, 3, and 4), far below the conventional critical value of 11.29 (see Section IV.C). Our instruments do not have sufficient variation to accurately discriminate among lagged τ^f_{t-j}'s.

Third, we do not impose the parametric restrictions on the $\tilde{\alpha}_j$'s and $\tilde{\beta}_j$'s in equation (D-4). While efficiency would be enhanced, a less restricted specification continues to generate unbiased and consistent estimates. We prefer a less restricted form to facilitate computation of the CCE estimator and our instrument search algorithm.

Appendix E: The Three-Step Procedure For Estimating The Non-Linear CCE Model

This appendix presents a more concise and formal statement of our three-step procedure for obtaining consistent estimates with the non-linear CCE estimator described in Sections IV.B and IV.D. We begin by reproducing equation (10) as equation (E-1),

$$\begin{aligned}\tau_{i,t} &= \alpha_0 \hat{\tau}^f_{i,t} + \sum_{n=1}^{N} \alpha_n \tau^f_{i,t-n} + x_{i,t}\beta + \varphi_i + \varepsilon_{i,t} \\ &\quad + \gamma_i \left(\bar{\tau}_t - \alpha_0 \bar{\hat{\tau}}^f_t - \sum_{n=1}^{N} \alpha_n \bar{\tau}^f_{t-n} - \bar{x}_t \beta \right),\end{aligned} \tag{E-1}$$

and rewriting it in the following concise notation,

$$\begin{aligned}&\tau_{i,t} = Q\left[\Pi^m, \Omega^n, \gamma^o\right] \\ &\qquad \Pi^m = \left\{\text{all } \alpha_i \text{ 's and } \beta \text{ from the first line in equation (E-1)}\right\} \\ &\qquad \Omega^n = \left\{\text{all } \alpha_i \text{ 's and } \beta \text{ from the second line in equation (E-1)}\right\} \\ &\qquad \gamma^o = \left\{\text{all } \gamma_i \text{ 's}\right\}\end{aligned} \tag{E-2}$$

where the m, n, and o superscripts index iterations.

Step 1 estimates the Π and Ω parameters pre-setting γ to 1.0,

$$\tau_{i,t} = Q\left[\Pi^1, \Omega^1, \gamma^o = 1\right]. \tag{E-3}$$

Step 2 estimates the Π and γ parameters pre-setting the Ω parameters to the estimates obtained in Step 1,

$$\tau_{i,t} = Q\left[\Pi^2, \Omega^1, \gamma^2\right], \tag{E-4}$$

and then iterates as follows,

$$\begin{aligned}\tau_{i,t} &= Q\left[\Pi^3, \Omega^2, \gamma^3\right], \\ \tau_{i,t} &= Q\left[\Pi^4, \Omega^3, \gamma^4\right],\end{aligned} \tag{E-5}$$

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until converge is achieved for each individual hth parameter $\pi_h \in \Pi$ and $\omega_h \in \Omega$ according to the following convergence criteria at the pth iteration,

$$\left| \pi^p_h / \omega^p_h - 1 \right| \leq 0.01. \tag{E-6}$$

Step 3 estimates the Π and Ω parameters pre-setting the γ parameters to the consistent estimates obtained at the conclusion of Step 2,

$$\tau_{i,t} = Q\left[\Pi^{p+1}, \Omega^{p+1}, \gamma^{p}\right]. \tag{E-7}$$

Equation (E-7) is linear in the parameters and is the basis for the CCE estimates presented in the paper.

Appendix F: Notes on the Specification of Dynamic Models

This appendix provides the details supporting our discussion in Section V.D that A) the standard lagged dependent variable (LDV) model is nested within a more general dynamic model that includes no LDV but an infinite number of time lags of the independent variables and B) a restricted version of this latter model can be estimated by including *N* lags of the independent variables and the *N+1st* lag of the LDV.

An "expanded" specification of our preferred model includes lags of all independent variables and is written as follows,

$$\tau_t = \sum_{n=0}^{N} \left(x_{t-n} \beta_n \right) + \varepsilon_t \tag{F-1}$$

where one of the variables in the x vector is the spatial lag of τ and *N* can go to infinity. (Note state subscripts have been omitted for expositional convenience.) Equation (F-1) is more general than our preferred specification in equation (10) because it contains additional lags. Equation (10) can be obtained from equation (F-1) by setting $\beta_n = 0$ for $n \geq 1$ in equation (F-1) and $\varphi_i = \varepsilon_{i,t} = \gamma_i = 0$ in equation (10).

Now consider the lagged dependent variable (LDV) model:

$$\tau_t = \rho\tau_{t-1} + x_t\beta + \vartheta_t , \tag{F-2}$$

where ϑ_t is an error term. The LDV can be eliminated by lagging this equation one period and substituting it into equation (F-2). The resulting equation contains the regressors x_t, x_{t-1}, and τ_{t-2}. The latter variable is eliminated by repeating the above procedure by lagging this transformed equation one period. If the procedure is repeated up to the *N+1st* period, we obtain the following equation,

$$\tau_t = \rho^{N+1}\tau_{t-N-1} + \sum_{n=0}^{N} \left(x_{t-n} \gamma_n \right) + \varepsilon_t , \tag{F-3a}$$

$$\gamma_n = \rho^n \beta , \tag{F-3b}$$

$$\varepsilon_t = \sum_{n=0}^{N} \rho^n \vartheta_{t-n} . \tag{F-3c}$$

The only important difference between our preferred model (equation (F-1)) and the LDV model (equation (F-3)) is the LDV term $\rho^{N+1}\tau_{t-N}$. (The less important differences involve redefining the coefficient vector on the x variables (equation (F-3b)) and the serial correlation in the error term (equation (F-3c).) The central point is that what we are omitting from our model is NOT last year's tax policy (τ_{t-1}), since the effects of this term are captured by the one-year lags of the x variables (and lagged error terms), but rather a term capturing the determinants of tax policy lagged more than *N* periods in the past. (The serial correlation in the error term does not pose any bias problems as long as the x variables are exogenous or instrumented.)

As *N* goes to infinity, ρ^{N+1} goes to zero, and the LDV term vanishes. It is in this sense that the LDV model is nested within a more general model with an infinite number of lags of x_{t-n}. In practice, the question of whether our omission of the LDV term from our estimating equation poses any problem depends on how far back lags of x_{t-n} could reasonably be expected to affect tax policy. The results presented in the paper for models without an LDV are based on a maximum lag of N=4. However, we also have estimated a model in which we set N=3 and then include the dependent variable lagged four periods (i.e., the term $\rho^{3+1}\tau_{t-3-1}$. These results are discussed briefly in Section V.D.