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STRATEGIC INTERACTION AMONG GOVERNMENTS: AN OVERVIEW OF EMPIRICAL STUDIES

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This article provides an overview of empirical models of strategic interaction among governments. To clarify the theoretical roots of such studies, the discussion shows how the empirical frameworks fit into two broad categories: spillover models and resource-flow models. Both types of models generate jurisdictional reaction functions, and the empirical task is to estimate such functions. When the estimated reaction-function slope is nonzero, the presence of strategic interaction is confirmed. The second part of the article reviews three econometric issues relevant to this estimation problem.

Keywords: *strategic interaction; spatial econometrics*

1. INTRODUCTION

Strategic interaction among governments has recently become a major focus of theoretical work in public economics. In the tax-competition literature, which represents an important segment of research in this area, governments levy taxes on a mobile tax base. When the number of jurisdictions is small, these taxes are chosen in strategic fashion, taking account of the inverse relationship between a jurisdiction's tax rate and its base (see Wilson 1999 for a survey). A related literature focuses on "welfare competition," analyzing income redistribution by state governments when the poor migrate in response to differentials in welfare benefits. In such models, states choose benefit levels in strategic fashion taking account of the mobility of the poor (see Brueckner 2000 for a survey). A third literature analyzes strategic interaction due to benefit "spillovers." A major line of research in this area focuses on choice of environmental standards by individual jurisdictions,

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recognizing that interaction arises through pollution spillovers (see Wilson 1996 for a survey). Spillovers can arise through different mechanisms in other types of models.

Spurred in part by these theoretical developments, strategic interaction among governments is now the focus of a growing empirical literature. The purpose of this short article is to provide an overview of this literature, highlighting its linkages to the underlying theoretical models while discussing the econometric issues it must confront. The discussion begins by showing how the theoretical models underlying most of the existing empirical studies can be separated into two main categories: spillover models and "resource-flow" models. The former category includes environmental models, while the latter category includes tax- and welfare-competition models. The discussion in section 2 provides a general characterization of each type of model and then shows how various examples in the literature represent special cases.

Both the spillover and resource-flow models generate a reaction function that shows how the decision variable for a given jurisdiction depends on the choices of other jurisdictions. Estimation of this reaction function is the goal of most empirical studies, and a number of econometric issues must be handled to do so successfully. These issues are discussed in section 3, and section 4 offers conclusions.

2. Categorization of Models

2.1. The Spillover Model

The empirical literature relies on two principal types of strategic-interaction models. Despite their differences, these models ultimately lead to the same empirical specification. The first type can be referred to as the spillover model. In this framework, each jurisdiction i chooses the level of a decision variable z_i, but the jurisdiction is also directly affected by the z's chosen elsewhere, indicating the presence of spillovers. Thus, jurisdiction i's objective function is written

$$V(z_i, z_{-i}; X_i), \tag{1}$$

where z_{-i} is the vector of zs for other jurisdictions and X_i is a vector of characteristics of i, which help determine preferences.

Jurisdiction i chooses z_i to maximize equation (1), setting $\partial V/\partial z_i \equiv V_{z_i} = 0$. Because this derivative depends on z_{-i} and X_i, the z_i solution depends on choices elsewhere and on jurisdiction i's characteristics. The solution can thus be written

$$z_i = R(z_{-i}; X_i). \tag{2}$$

The function R represents a reaction function, which gives jurisdiction i's best response to the choices of other jurisdictions. Note that the position of the reaction function depends on jurisdiction i's characteristics.

Theory is silent regarding the sign of the reaction function's slope. Differentiation of the above first-order condition shows that $\partial z_i/\partial z_{-i} = -V_{z_i z_{-i}} / V_{z_i z_i}$, where the expressions are the second partial derivatives of V. Although $V_{z_i z_i}$ must be negative for the second-order condition to be satisfied, $V_{z_i z_{-i}}$ (which represents a vector of derivatives) can take either sign, depending on the properties of preferences.[1] Thus, the slope $R_{z_{-i}}$ of the reaction function (again a vector expression) can be positive or negative. While the slope could also be zero, this outcome represents a knife-edge case of little practical interest. Note, however, that the reaction function's slope will be identically zero in the case where spillovers are absent, with z_{-i} not appearing in equation (1). Thus, a test of the null hypothesis that the reaction function's slope is zero is effectively a test for the existence of spillovers.

The spillover model underlies a number of the existing empirical studies of strategic interaction. The earliest paper in the literature, the study of Case, Rosen, and Hines (1993), is based on this model. Their empirical framework assumes that residents of each U.S. state benefit from public expenditure in other states, as well as from their own state's spending. Residents of California, for example, might benefit from spending on roads in Arizona, which would affect the convenience of vacation travel in that state. To derive V for this case, let the preferences for a representative resident of state i be given by $U(c_i, e_i, e_{-i}; \widetilde{X}_i)$, where c_i is private consumption, the es represent spending per capita in state i and other states (replacing the zs in equation [1]), and $\widetilde{X}_i$ represents state characteristics aside from income. Letting y_i denote per capita income in state i, the individual budget constraint is $c_i = y_i - e_i$, and substitution then yields $U(y_i - e_i, e_i, e_{-i}; \widetilde{X}_i) \equiv V(e_i, e_{-i}; X_i)$. Relying on such a model, Case, Rosen, and Hines estimated state-expenditure reaction functions. Murdoch, Rahmatian, and Thayer (1993) carried out a similar exercise, focusing on city-level spillovers in recreation expenditures and estimating reaction functions using municipal data. Kelejian and Robinson (1993) estimated a related model based on county-level spillovers of police expenditures.

Environmental models also fit in the spillover context, as mentioned above. To derive V for such a model, let consumer preferences be given by $U(c_i, p_i; \widetilde{X}_i)$, where p_i is the pollution level in jurisdiction i. Also, let a_i and a_{-i} represent pollution abatement expenditures in the different jurisdictions, taking the place of the zs in equation (1). For simplicity, suppose that pollution disperses evenly, so that pollution levels are the same everywhere and depend on the total abatement expenditures across all n jurisdictions. Thus, $p_i = P(\Sigma_{j=1}^{n} aj)$, $P' < 0$. Eliminating c_i using the budget constraint and substituting for p_i, jurisdiction i's objective function is then $U[y_i - a_i, P(\Sigma a_j); \widetilde{X}_i] \equiv V(a_i, a_{-i}; X_i)$. Note that an increase in abatement in another jurisdiction benefits residents of i.[2] This type of model forms the basis for the empirical studies of Murdoch, Sandler, and Sargent (1997) and Fredriksson and Millimet (2002), which estimate pollution-abatement reaction functions for European countries and U.S. states, respectively.

The yardstick-competition model of Besley and Case (1995) also fits within the spillover framework. In the model, voters look at public services and taxes in other jurisdictions to help judge whether their government is wasting resources (through inefficiency or rent seeking) and deserves to be voted out of office. Although Besley and Case developed this idea using a sophisticated information-theoretic framework, the essence of the approach can be illustrated as follows, using a simple but incomplete model.

Consumer preferences are now given by $U(y_i - T_i, q_i; \tilde{X}_i)$, where T_i is a tax payment and q_i represents the level of a public good. Taxes cover the minimal production cost of the public good plus any extra resources lost to waste or rent seeking. These lost resources cannot be observed by voters, but their extent is gauged by comparisons to other jurisdictions. Suppose, in particular, that these comparisons yield a minimum level of public good provision relative to taxes (q_i/T_i) that must be delivered for jurisdiction i's government to remain in office. This required level depends on observed public good levels relative to taxes in other jurisdictions, and it can be written $q_i/T_i = \phi[(q/T)_{-i}]$. By indicating a more favorable relationship between q and taxes elsewhere, an increase in any of the ratios q_j/T_j, $j \neq i$, forces i's government to raise q_i/T_i (ϕ is thus increasing in its arguments). Writing q_i as $T_i\phi$, preferences can then be rewritten as

$$U\{y_i - T_i, T_i\phi[(q/T)_{-i}]; \tilde{X}_i\} \equiv V(T_i, T_{-i}; X_i). \tag{3}$$

Note that by worsening outcomes elsewhere, an increase in T_j (with q_j held fixed) harms residents of jurisdiction i, allowing q_i to be reduced for a given T_i.[3] In this way, information spillovers from other jurisdictions affect the delivery of public services to i's residents.

Relying on such a model, Besley and Case (1995) estimated tax reaction functions at the state level, using the total state tax burden as the variable of interest. Also relying on a model of yardstick competition, Bivand and Szymanski (1997, 2000) estimated reaction functions involving public-sector costs, focusing on the costs of local garbage collection in Britain.

2.2. *The Resource-Flow Model*

A second type of strategic-interaction framework can be referred to as a resource-flow model. In this model, a jurisdiction is not affected directly by the z levels in other jurisdictions. But the jurisdiction is affected by the amount of a particular "resource" that resides within its borders. Because the distribution of this resource among jurisdictions is affected by the z choices of all, jurisdiction i is indirectly affected by z_{-i}. In this model, jurisdiction i's objective function is written

$$\tilde{V}(z_i, s_i; X_i), \tag{4}$$

where s_i is the resource level enjoyed by i. The distribution of resources depends on the entire z vector as well as on jurisdiction characteristics. Thus, the resources available to i are given by

$$s_i = H(z_i, z_{-i}; X_i). \tag{5}$$

Note that since X_i can be measured relative to the average characteristics of all jurisdictions, X_{-i} need not appear in equation (5).

To derive the reduced form of the resource-flow model, equation (5) is substituted into (4), yielding

$$\tilde{V}[z_i, H(z_i, z_{-i}; X_i); X_i] \equiv V(z_i, z_{-i}; X_i). \tag{6}$$

Thus, even though the underlying model is different, this objective function has the same form as equation (1), with z_i, z_{-i}, and X_i appearing as arguments. As a result, maximizing equation (6) by choice of z_i yields a reaction function like equation (2). The properties of this function are now more complex, with its slope depending jointly on the properties of the H and $\tilde{V}$ functions. As before, however, the reaction function's slope is ambiguous in sign.

The tax-competition model represents the best-known example of the resource-flow framework. In the model, jurisdictions produce a private good using mobile capital and immobile labor, with $f(k_i)$ giving the intensive form of the common production function and k_i representing capital per worker in jurisdiction i (the resource s_i). Jurisdictions, which are assumed for simplicity to have identical population sizes, levy a tax on locally employed capital, with t_i denoting the tax per unit in i (which plays the role of z_i). Since capital moves across jurisdictions to equalize net-of-tax returns, its distribution must satisfy

$$f'(k_j) - t_j = \rho, \qquad j = 1, \ldots, n \tag{7}$$

$$\sum_{i=1}^{n} k_j = n\bar{k}, \tag{8}$$

where ρ is the endogenous net return and $\bar{k}$ is the economy-wide level of capital per worker. Equations (7) and (8) determine k_j, $j = 1, \ldots, n$, and ρ as functions of all the tax rates, with

$$k_i = H(t_i, t_{-i}) \tag{9}$$

$$\rho = G(t), \tag{10}$$

where t represents the entire vector of tax rates.[4] Differentiation of equations (7) and (8) establishes $H_{t_i} < 0$, indicating that capital flees jurisdiction i when t_i increases, while showing that ρ falls when any of the tax rates rises.

Tax revenue is used to provide a public good q_i that has private characteristics. With q_i produced at unit cost, its level is then given by t_ik_i, which equals tax revenue per worker. Individual consumption of the private good, again denoted c_i, is equal to the wage $w(k_i)$, which depends positively on k_i, plus income from ownership of capital, which equals $\rho\bar{k}$ (consumers own equal shares of the total).

Combining all the above information, preferences $U(c_i, q_i; \tilde{X}_i)$ can be written

$$U[w(k_i) + \rho\bar{k}, t_ik_i; \tilde{X}_i] = U\{w[H(t_i, t_{-i})] + G(t)\bar{k}, t_iH[t_i, t_{-i}]; \tilde{X}_i\}$$
$$\equiv V(t_i, t_{-i}; \tilde{X}_i). \qquad (11)$$

Thus, the objective function ultimately depends on jurisdiction i's tax rate and rates elsewhere. In choosing t_i, the jurisdiction takes account of the flight of capital caused by an increase in its tax rate, which moderates the incentive to raise t_i, while recognizing that a tax increase also depresses capital's net return ρ. Because the impact of the higher t_i depends on tax rates elsewhere, the optimal value depends on these rates, yielding a reaction function like equation (2). Brueckner and Saavedra (2001) presented an example based on specific functional forms showing that the slope of this function may be positive or negative, as noted above.

Brueckner and Saavedra (2001) also estimate tax reaction functions, focusing on property taxes for cities in the Boston metropolitan area. Other empirical studies that the rely on the tax-competition model to motivate the estimation of tax reaction functions include Brett and Pinkse (2000), who focused on local property taxes in Canada; Buettner (2001), who studied the local business tax in Germany; and Hayashi and Boadway (2001), who focused on provincial corporate income taxes in Canada. Ladd (1992), Heyndels and Vuchelen (1998), and Revelli (2001a, 2001b) have also looked for strategic behavior in the choice of local taxes (in the United States, Belgium, and the United Kingdom, respectively), but these studies are agnostic about the source of the interaction. They recognize that tax competition may be one source but that yardstick competition or some other type of behavior related to spillovers may also generate strategic interaction. Accordingly, they refer to interaction as "tax mimicking," a phrase that does not pin down the underlying cause of the behavior.

Models of welfare competition also fall into the resource-flow category.[5] In such models, the altruistic rich in jurisdiction i provide a transfer b_i to the poor, who also work at low-skill jobs (the transfer plays the role of z_i). The low-skill wage in i equals $w(L_i)$, where L_i represents i's poor population and $w' < 0$ (L_i plays the role of the resource s_i). Poor gross income in i then equals $w(L_i) + b_i \equiv Y_i$.

Since migration of the poor equalizes gross incomes across jurisdictions, the distribution of the poor population must satisfy

$$w(L_j) + b_j = Y \qquad j = 1, \ldots, n \qquad (12)$$

$$\sum_{j=1}^{n} L_j = \bar{L}, \tag{13}$$

where Y is the endogenous, uniform level of gross income and $\bar{L}$ is the total number of poor in the economy. In similar fashion to the tax-competition model, equations (12) and (13) yield solutions for Y and L_j, $j = 1, \ldots, n$, as functions of the transfers in all jurisdictions. For jurisdiction i, the latter solution can be written

$$L_i = H(b_i, b_{-i}). \tag{14}$$

Differentiation of equations (12) and (13) establishes $H_{b_i} > 0$, so that jurisdiction i's poor population increases when its transfer rises.

The preferences of the rich in jurisdiction i are given by $U(c_i, Y_i; \tilde{X}_i)$. Their budget constraint is $c_i = y_i - b_iL_i/m$, where m is the uniform number of rich in each jurisdiction and y_i gives the exogenous rich income in i. Substituting, the objective function may then be written

$$U[y_i - b_iL_i/m, w(L_i) + b_i; \tilde{X}_i] = U\{y_i - b_iH[b_i, b_{-i}]/m, w[H(b_i, b_{-i})] + b_i; \tilde{X}_i\}$$

$$\equiv V(b_i, b_{-i}; X_i). \tag{15}$$

In choosing b_i, the jurisdiction takes account of the inflow of the poor caused by a higher transfer, which tends to moderate the incentive for redistribution. Because the magnitude of this inflow depends on benefit levels elsewhere, the optimal b_i depends on these benefits, again yielding a reaction function like equation (2). Brueckner (2000) demonstrated that, as before, the reaction function can slope up or down. For studies that estimate welfare reaction functions using U.S. data, see Figlio, Kolpin, and Reid (1999) and Saavedra (2000).

A third example of the resource-flow model is provided by Brueckner (1998), who analyzed strategic interaction in the choice of growth controls by California cities. In this case, the mobile resource is the population of renters. This population is controlled by each community through limitations on density and new construction, and the goal is to raise house prices, generating capital gains for homeowners. The optimal stringency of growth controls in a given community depends on their stringency elsewhere, again yielding a reaction function like equation (2).

2.3. *Other Models*

In almost all the empirical studies discussed above, the estimated reaction function is upward sloping. Thus, the decision variables of the interacting governments represent "strategic complements." In each case, the emergence of a nonzero slope coefficient confirms the presence of strategic interaction, which may arise either from interjurisdictional spillovers or from each government's awareness that its decisions affect resource flows.

The evidence of positive interaction appears to be connected to an important feature shared by all the models discussed above, which has not been explicitly mentioned so far. This feature is a common focus on "horizontal" interaction among governments at the same level (local, state, or national). Another kind of model focuses on vertical interaction among governments at different levels, and such models can generate downward-sloping empirical reaction functions (indicating that decision variables are "strategic substitutes"). These vertical-interaction models, however, do not neatly fit into either the spillover or resource-flow framework, a consequence of the inherent asymmetry resulting from consideration of governments at different levels.

The existing models of this type focus on the interaction arising from taxation of a common tax base by governments at different levels. Besley and Rosen (1998), Hayashi and Boadway (2001), Goodspeed (2000), and Esteller-Moré and Solé-Ollé (2001) have studied interaction between national and provincial (or state) governments. Besley and Rosen, along with Esteller-Moré and Solé-Ollé, have studied interaction in the United States, focusing on commodity taxes and income taxes, respectively. Hayashi and Boadway focused on Canadian corporate income taxes, and Goodspeed studied income taxes in Europe. Although Besley and Rosen as well as Esteller-Moré and Solé-Ollé found upward-sloping state reaction functions, both Hayashi and Boadway and Goodspeed estimated reaction functions for lower-level governments that are downward sloping.[6] Several of these studies assumed Stackelberg leadership on the part of the national government, while Hayashi and Boadway tested for such behavior, confirming its presence.[7]

3. Econometric Issues

As seen above, both the spillover and resource-flow models of strategic interaction generate reaction functions, which relate each jurisdiction's chosen z to its own characteristics and to the choices of other jurisdictions. The goal of empirical work is to estimate such functions, and following equation (2), the estimating equation can be written

$$z_i = \beta \sum_{j \neq 1} \omega_{ij} z_j + X_i \theta + \varepsilon_i, \tag{16}$$

where β and θ are unknown parameters (the latter a vector), ε_i is an error term, and the ω_{ij} represent nonnegative weights, which are specified a priori. These weights indicate the relevance of other jurisdictions j in the process of interaction, and they can be viewed as part of jurisdiction i's characteristics. The weights typically capture the location of i relative to other jurisdictions, and a scheme that assigns weights based on contiguity is commonly used. Under such a scheme, $\omega_{ij} = 1$ for jurisdictions j that share a border with i and $\omega_{ij} = 0$ for noncontiguous jurisdictions. Once the pattern of interaction has been specified, the weights are normalized so that their sum equals unity for each i.

While choice of the weights is based on prior judgement about the pattern of interaction, the parameter β, which reflects the strength of interaction among jurisdictions, is estimated from the data. Note that equation (16) implies that the direction of i's interaction with all other jurisdictions is the same, with its sign determined by the sign of β. The magnitude of the effect, however, depends on the relevant weight, with $\partial z_i/\partial z_j = \beta\omega_{ij}$.

As is well known from the literature on spatial econometrics (see Anselin 1988), three econometric issues must be confronted in estimating equation (16). These are (1) endogeneity of the z_js, (2) possible spatial error dependence, and (3) possible correlation between X_i and the error term. These issues are considered in turn in the following discussion.

3.1. *ENDOGENEITY OF THE z_jS*

Because of strategic interaction, the z values in different jurisdictions are jointly determined. As a result, the linear combination of the z_js appearing on the right hand side (RHS) of equation (16) is endogenous and correlated with the error term ε_i. To see this formally, the first step is to rewrite equation (16) in matrix form, which yields

$$z = \beta W z + X\theta + \varepsilon, \tag{17}$$

where z is the vector of the z_is, X is the characteristics matrix, and W is the weight matrix, with representative element ω_{ij}. Then, equation (17) can be used to solve for the equilibrium values of the z_is, which yields

$$z = (I - \beta W)^{-1}X\theta + (I - \beta W)^{-1}\varepsilon. \tag{18}$$

Note that the solution in equation (18) gives the Nash equilibrium generated by interaction among the jurisdictions. The key implication of equation (18) is that the random component of z_k is equal to the inner product of the kth row of the matrix $(I - \beta W)^{-1}$ and the error vector ε. With each element of z thus depending on all the εs, it follows that each of the z_js on the RHS of equation (16) depends on ε_i, the equation's error term. The resulting correlation means that ordinary least squares (OLS) estimates of the parameters of equation (16) are inconsistent, requiring use of an alternate estimation method.

Two such methods are employed in the literature. Under the first method, the reduced form equation given by equation (18) is estimated using maximum likelihood (ML) methods. Note that since the key parameter β enters nonlinearly in this equation, a nonlinear optimization routine must be used to estimate it. Among the horizontal-interaction studies cited above, those using the maximum likelihood approach are Case, Rosen, and Hines (1993); Murdoch, Rahmatian, and Thayer (1993); Besley and Case (1995); Bivand and Szymanski (1997, 2000); Brueckner

(1998); Murdoch, Sandler, and Sargent (1999); Saavedra (2000); and Brueckner and Saavedra (2001).

The second method is an instrumental variables (IV) approach. Under this approach, a typical procedure is to regress Wz on X and WX and to use the fitted values $\hat{W}z$ as instruments for Wz. Note that this procedure involves regressing the weighted linear combination of the z_js from the RHS of equation (16) on X_i and on the same linear combination of the X_js. In effect, each of the z_js is thus viewed as depending on its associated X_j vector and on X_i. Like the ML method, the IV approach also yields consistent estimates of the parameters of equation (16).

Horizontal-interaction studies that use the IV approach are Ladd (1992); Kelejian and Robinson (1993); Brett and Pinkse (2000); Heyndels and Vuchelen (1998); Figlio, Kolpin, and Reid (1999); Fredriksson and Millimet (2000); Buettner (2001), and Revelli (2001a, 2001b). In constrast to these papers and those using the ML approach, Hayashi and Broadway (2001) avoided the endogeneity issue entirely. They did so by assuming that interaction occurs with a time lag, so that the z values on the RHS of equation (16) are lagged one or more periods. With simultaneity thus eliminated, OLS estimation yields consistent estimates.

3.2. *Spatial Error Dependence*

The presence of spatial dependence in the errors also complicates the estimation of equation (16). When spatial error dependence is present, the error vector ε satisfies the relationship

$$\varepsilon = \lambda M\varepsilon + v, \tag{19}$$

where M is a weight matrix often assumed to be the same as W in equation (17), v is well-behaved error vector, and λ is an unknown parameter.

Spatial error dependence arises when ε includes omitted variables that are themselves spatially dependent. For example, suppose that z measures the park acreage in a community, and suppose that such acreage is inversely related to natural topographical features such as beachfront, riverfront, adjacent mountains, and so on. Such features encourage outdoor recreation without the need for community investment in parks, and they are likely to be unmeasured and thus part of the error term ε (natural features enter negatively in ε). A key fact, however, is that topographical features are spatially correlated, with their presence (absence) in one community usually implying their presence (absence) in nearby communities. This correlation generates spatial dependence in the error term ε.

When this spatial error dependence is ignored, estimation of equation (17) can provide false evidence of strategic interaction. To understand this outcome, suppose that $\beta = 0$, so that strategic interaction in the choice of park acreage is actually absent. Then, note from above that ε (and hence z) will be low in communities with good natural topographical features, while ε and z will be high in communities with poor natural features. But since communities of each type will tend to be near one another because of spatial dependence in the errors, estimation of equation (16) will indicate a positive association between the z levels in nearby communities, yielding a positive estimate of β. This result, however, reflects spatial error dependence and not strategic interaction.

To deal with this problem, one approach is to use ML to estimate equation (17), taking account of the error structure in equation (19). This approach, which is implemented by Case, Rosen, and Hines (1993), is computationally challenging. In addition, the similar roles played by the parameters β and λ in the model may lead to difficulties in identifying their individual magnitudes (see Anselin 1988).

An easier remedy is to rely on the IV estimation method discussed above. Kelejian and Prucha (1998) showed that this method generates a consistent estimate of β even in the presence of spatial error dependence. A third approach is to estimate equation (17) by ML under the assumption that spatial error dependence is absent, relying on hypothesis tests to verify this absence. Because a test based on the ML results themselves is invalid if spatial dependence is actually present, the robust tests of Anselin et al. (1996) can be employed instead. These tests are based on OLS estimates of equation (17), and they are not contaminated by uncorrected spatial error dependence. This approach is used by Bivand and Szymanski (1997, 2000), Brueckner (1998), Saavedra (2000), and Brueckner and Saavedra (2001).

3.3. Correlation between X_i and ε_i

If the jurisdiction characteristics in X_i are correlated with the error term, then both the ML and IV estimates discussed above are inconsistent. Such correlation could arise, for example, through endogenous sorting of households across communities. In the park case, suppose that high-income households have a high demand for natural topographical features and thus end up residing in the low-ε communities possessing such features. The result is a negative correlation between community income (an element of X_i) and ε_i. This correlation leads to an inconsistent estimate of the income coefficient while also potentially distorting the estimates of the remaining coefficients in the equation.

While this problem can be addressed if suitable instruments for the offending X_i variable(s) are available, finding such instruments can be difficult. An alternative approach, however, is to use panel data. With such data, all time-invariant community characteristics, observed or unobserved, can be represented by community-specific intercepts. In effect, the estimate of β is then generated by estimating equation (17) in first-difference form. Although some of the correlation between X_i and ε_i may remain if the unobserved community characteristics generating it are time-varying and thus not purged by first differencing, much of the correlation is likely to be eliminated. For studies using this approach, see Figlio, Kolpin, and Reid (1999) and Revelli (2001a).

Use of panel data may also help eliminate spatial error dependence, which arises through spatial autocorrelation of omitted variables. When the influence of such variables is captured in community-specific intercept terms, the remaining error term in the equation may exhibit little spatial dependence. As before, however, this remedy is incomplete when the offending omitted variables are strongly time dependent and thus imperfectly captured by the community-specific intercepts.

4. CONCLUSION

This article has provided an overview of empirical models of strategic interaction among governments. To clarify the theoretical roots of such studies, the discussion shows how the empirical frameworks fit into two broad categories: spillover models and resource-flow models. Empirical papers that focus on strategic choice of environmental standards, on yardstick competition, and on public expenditure spillovers were all shown to fit within the spillover model. Papers that focus on tax competition and welfare competition represent special cases of the resource-flow model.

Both types of models generate jurisdictional reaction functions, and the empirical task is to estimate such functions. When the estimated reaction-function slope is nonzero, the presence of strategic interaction is confirmed. The second part of the article reviewed three econometric issues relevant to this estimation problem: endogeneity of the choice variables of other jurisdictions, which appear on the RHS of the reaction function; spatial error dependence; and correlation between jurisdiction characteristics and the error term.

In conclusion, it must be stressed that, while successful handling of these empirical issues leads to reliable estimates of reaction-function parameters, such estimates do not directly reveal the nature of the behavior underlying the observed interaction. For example, a nonzero slope for a tax reaction function is consistent with both the yardstick-competition and tax-competition models, and to discriminate between the models, additional evidence is needed. Such evidence can come from estimates of the structural equations that generate the reaction function. For example, to substantiate the comparative behavior underlying the yardstick-competition model, Besley and Case (1995) estimated an auxiliary equation that relates voter approval of an incumbent to taxes in neighboring jurisdictions (expecting a positive coefficient).

Similarly, to support their view that tax-competition behavior underlies interaction in the choice of tax rates, Brett and Pinkse (2000) estimated an equation relating a jurisdiction's tax base to its tax rate (expecting a negative coefficient). By illuminating the source of the interaction, such auxiliary evidence lends credibility to claims, based on reaction-function estimates, that governments engage in strategic behavior. As a result, it is a desirable feature of future work.

Notes

1. Note that the forms of both $V_{z_i z_{-i}}$ and $V_{z_i z_i}$ will depend on the details of the model used, as can be seen by referring to the examples later in the article.

2. Note that in a more realistic formulation, jurisdiction *i* would be affected most by the *a* levels of nearby jurisdictions.

3. Equilibrium values for the *q*s and *T*s would be determined as follows. T_i would be chosen to maximize equation (3), giving an optimal value conditional on $(q/T)_{-i}$ and X_i for $i = 1, \ldots, n$. The relationship $q_i/T_i = \phi[(q/T)_{-i}]$, $i = 1, \ldots, n$, then provides *n* additional equations. This system of 2*n* equations determines equilibrium values for q_i and T_i, $i = 1, \ldots, n$.

4. Note, in contrast to equation (10), *i*'s tax rate in equation (9) must be distinguished from those in other jurisdictions in determining k_i.

5. The ensuing discussion follows Brueckner (2000), which in turn drew on Wildasin (1991).

6. Although Revelli (2001a) focused mainly on horizontal interaction, he allowed for vertical interaction as well in his empirical model.

7. Hayashi and Boadway (2001) simultaneously considered horizontal interaction between Canadian provincial governments, as noted above. Esteller-Moré and Solé-Ollé (2001) also incorporated horizontal interaction between the U.S. states, and their results showed that this interaction is positive.

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