A commuting-based refinement of the contiguity matrix for spatial models, and an application to local police expenditures

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Abstract

One of the main weaknesses of empirical models in regional science and urban economics involving spatial interdependence is the arbitrary nature of the weight matrix. The paper considers a refinement of the commonly used contiguity matrix which exploits information on commuting flows between locations. Within the set of contiguous jurisdictions, the matrix assigns higher weights to localities for which commuting patterns suggest that households would view them as substitute locations to reside in. The concept is then applied to cities and townships in New England. Using the expenditure competition effect on local police spending as an example, we show that commuting-adjusted weighting schemes give estimates which differ substantially from those obtained using a standard contiguity matrix.

Keywords: Spatial weights; contiguity matrix; commuting flows; police expenditures

JEL Classification: C21, H72, H77

1 Introduction

Empirical studies dealing with cross-sectional dependence require assumptions about the potential dependence between units of observation. In an application involving N cross-sectional units, a researcher will usually proceed by defining an $N \times N$ matrix of spatial weights, specifying, for each unit i, the degree of 'neighborliness' of the $N-1$ other

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units. Since the weight matrix has to be imposed a priori, it is commonly seen as a critical component of empirical models with spatial effects (Cliff and Ord, 1981; Upton and Fingleton, 1985; Anselin, 1988).

Given the nature of the problem, the vast majority of studies choose some arbitrary matrix and then perform some 'sensitivity' analysis in the form of estimations using alternative (but equally arbitrary) matrices. Because the chosen matrices may or may not correspond to the true pattern of cross-sectional dependence, the identification of the effects of interest often remains questionable. Nevertheless, among spatial econometrics practitioners a broad consensus about two fairly general rules for defining weight matrices has emerged. The first rule says that 'distance matters', and that weights should be defined such that, from an a priori perspective, the interdependence between units is stronger if they are closer (in geographical terms) to each other. To adhere to this rule, researchers have frequently used some measure of distance decay or sets of k nearest neighbors. The most common way to operationalize the notion that interdependence is negatively related to distance, however, is to employ the criterion of contiguity, where units are defined as neighbors if they share a common border. A contiguity-based weight matrix will thus, for each unit, assign strictly positive weights to contiguous units and weights equal to zero to all others. The second rule requires that, in order to avoid further difficulties in identifying the spatial effects of interest, the weights must be exogenous to the model (Manski, 1993). Referring to this rule, Baicker (2005) has criticized the methodology employed by Case et al. (1993) in their study of spillover effects of state spending for using weights which were based on the difference in the percentage of the population that is black. Baicker argued that a characteristic like the percent of the population that is black is likely to be correlated with omitted variables in a state spending equation. Because in the standard procedures to estimate models of cross-sectional policy interdependence the weights are being used to construct instruments for neighbors' policies, correlation between the weights and unobservables leads to an endogeneity issue that cannot be resolved easily.[1] The requirement that the weights be exogenous to the model is usually seen as supportive to the use of simple distance

[1] Baicker also notes that endogenous weights are equally problematic if estimation is done by maximum likelihood.

or contiguity-based matrices, because the underlying geographical structure is arguably exogenous in most applications (e.g., Cliff and Ord, 1981; Revelli, 2003).

However, using only physical distance to define spatial weights may also come at a cost. Most importantly, it selects neighbors without taking into account the fact that economic and social characteristics may well play an important role in shaping the true set of reference jurisdictions. If the choice of a weight matrix is essentially an issue of choosing a specification for an estimable equation, ignoring economic determinants and defining purely geography-based weights might lead to problems of misspecification.

This paper discusses a refinement of the contiguity matrix for applications involving a Tiebout-like economy of local jurisdictions. The underlying idea is to derive weights that capture the degree of substitutability of jurisdictions as places of residence. This is done by comparing the pattern of commuting flows originating from contiguous locations, and constructing a matrix that assigns higher weights to localities for which such a comparison suggests that households would view them as substitute locations to reside in. To give an example, if two adjacent communities within a metropolitan area have all their residents commuting downtown, we can think of these communities as places of residence being perfectly specialized to serve households working in the downtown area. This pattern of specialization suggests that for the average commuter-household living in either of the communities, the other community can be considered a close substitute. In contrast, if the commuting patterns of two communities are very different, it is unlikely that the average commuter-household living in either of them would consider the other community as an alternative place of residence. Hence, comparing commuting patterns and assigning large weights to communities with similar patterns effectively means to select neighbors of local jurisdictions which can be thought of being engaged in policy competition for the same set of residents.

It is worth noting that the idea to define a weight matrix capturing the degree of substitutability between locations has been expressed before. In the context of business tax competition, for instance, Brett and Pinkse (2000) argue that the weight matrix should select those locations as 'neighbors' which are substitute locations for firms to do business in. However, little attempts have been made so far to quantify the substitutability of alternative localities beyond concepts involving arbitrary forms of distance-decay.

To show the effect of adjusting a matrix of contiguity weights by a measure for the similarity of commuting patterns in a standard application, the study compares the performance of various matrices in estimations of an expenditure competition model for the sample of 559 cities and townships in Connecticut, Massachusetts, and Rhode Island. Using local police expenditures as an example, it is shown that when commuting-based weights are employed, the estimates for the expenditure competition effect differ substantially from those obtained from standard schemes based on contiguity and community size. We also address the issue of a potential endogeneity of the commuting-based matrix by using historical commuting data to construct the weight matrix.

The paper is related to an extensive literature on spatial model specification in applications addressing cross-sectional policy interdependence. Models of expenditure and welfare competition are estimated by Case et al. (1993), Figlio et al. (1999), Saavedra (2000), Revelli (2003) and Baicker (2005). Murdoch et al. (1997) and Fredriksson and Millimet (2002) consider reaction functions for policies of pollution abatement for European countries and U.S. states, respectively. Based on theoretical work by Brueckner (1995) and Helsley and Strange (1995), Brueckner (1998) analyzes interdependencies between growth control measures in California cities, while Bivand and Szymanski (1997) discuss the case of garbage collection costs in English districts. A considerable number of studies deal with estimating tax reaction functions for local jurisdictions (e.g., Besley and Case, 1995; Brett and Pinkse, 2000; Brueckner and Saavedra, 2001; Buettner, 2001; Bordignon et al., 2003).[2] Finally, Rincke (2006, 2007) studies interdependencies in the propensity of U.S. school districts to adopt innovative school choice policies.

As mentioned above, most of the empirical studies impose some arbitrary weight matrix, usually based on physical distance and, although less often, relative jurisdiction size.[3] There are, however, some noteworthy exceptions. Baicker (2005) constructs a matrix

[2]Brueckner (2003) and Revelli (2005) provide surveys of the literature focussing on public finance applications.

[3]For illustrative examples, see Brueckner (1998) and Brueckner and Saavedra (2001).

from the degree of population mobility between states to estimate spillover effects of state spending. In their study on the demand for emission reductions, Murdoch et al. (1997) quantify the spatial association among European countries from the origin of Oxidized Sulphur and Nitrogen depositions in the soil of the regions considered. Another example where the weight matrix is suggested by the nature of the application is Rincke (2006), who exploits institutional limitations to the mobility of students to derive a spatial structure for the analysis of the adoption of public school choice by Michigan school districts.

The remainder of the paper is organized as follows. Section 2 introduces the commuting-based refinements of the contiguity matrix. In Section 3, we apply the concept to local jurisdictions from New England and discuss the performance of various refined contiguity matrices in a model of expenditure competition. Finally, Section 4 offers some concluding remarks and suggestions how to use the concept in empirical work using country instead of local data.

2 The concept: A commuting-based refinement of the contiguity matrix

In this section, we derive a simple concept for deriving, for each location $i = 1, \ldots, N$, a set of localities that households would view as substitute locations to reside in. The concept can be applied fairly generally, but we prefer to discuss the approach as a refinement of the contiguity matrix as the most common way to quantify the spatial association among localities. We do this for two reasons. First, contiguity can safely be regarded as exogenous in most applications. Consequently, a refinement of the contiguity matrix will be less likely to be endogenous compared to a matrix that is determined without taking into account the physical distance between locations. Second, discussing commuting-based weights as a refinement of a standard approach to determine a spatial structure facilitates comparison to earlier work in the field. However, the following treatment can easily be extended to cover commuting-based refinements of other standard concepts such as, for instance, k nearest neighbors.[4]

The idea of the refinement is to capture empirically the degree of substitutability of communities as places of residence by exploiting information conveyed in the choices of households on the housing market. In practical terms, we want to derive a measure for the substitutability of communities from comparing the patterns of outbound commuting originating from the locations under consideration. This is motivated by the fact that all households reveal their most preferred community by choosing a place of residence. Effectively, we can think of jurisdictions as specializing to serve households associated to a particular set of workplaces. If two communities specialize in a similar way, i.e. if they end up with sets of resident households with similar commuting behavior, these communities can be thought of as being close substitutes from the point of view of the 'average' household living in either of them. Ideally, one would want to evaluate commuting patterns in subgroups of households, differentiated along dimensions such as, for instance, the type of occupation. However, the purpose of the study is to establish a way of quantifying the degree of substitutability between locations such that the concept can be used in a wide range of applications. Since publicly available place-to-place data on the gross number of commuters is typically not differentiated by occupation (or any other dimension), it seems most useful to rely on the total number of outbound commuters and to avoid further complications.[5]

The construction of the refined contiguity matrix is straightforward. For an economy consisting of N jurisdictions, let c_{ij} denote the number of commuters living in i and working in j. Our (inverse) index for the similarity of the pattern of commuting originating

[4]In practical terms, the focus on matrices involving some sort of distance decay is not particularly restrictive. The fact that commuting is a local phenomenon ensures that the commuting-based weight schemes discussed below assign the highest weights to physically close locations even if no distance-decay is explicitly imposed. This is documented in an earlier version of this study which is available from the author upon request.

[5]For instance, the Census Bureau publishes place-to-place commuting data without any differentiation by occupation. This is because the main purpose of the data is to support the planning of road and public transportation infrastructure.

from i and j is

$$s_{ij} = \frac{1}{2} \sum_{k \neq i,j} \left| \frac{c_{ik}}{\sum\limits_{m \neq i,j} c_{im}} - \frac{c_{jk}}{\sum\limits_{m \neq i,j} c_{jm}} \right|, \tag{1}$$

where $c_{ik}/\sum_{m \neq i,j} c_{im}$ is the share of commuters residing in i and working in k among all commuters living in i and working in some place $m \neq i, j$. By taking the difference with the respective share for community j and adding up the differences in absolute values across all $N-2$ communities (potentially) receiving commuters from i and j, s_{ij} takes values (after multiplication by the scale factor 1/2) between a minimum of zero, indicating identical shares of commuters going to all places $k \neq i, j$, and a maximum of one, indicating that there is no place $k \neq i, j$ receiving commuters from both i and j.

One should note that within community flows (households living and working in the same location) are not considered in Equ. (1). The reason is that doing so would yield results for the similarity index s running opposite to what the index is supposed to measure. To give an example, consider two locations i and j with all residing households working in their home community. With all inter-community flows equal to zero, s_{ij} will not be defined. If we, however, defined the shares as $c_{ik}/\sum\limits_{m \neq j} c_{im}$ and $c_{jk}/\sum\limits_{m \neq i} c_{jm}$, respectively, and added to the right-hand side of Equ. (1) a term capturing the difference between i and j in the share of households commuting within their home community, the similarity index would attain a value of zero, indicating perfect similarity between i and j. This would clearly be an undesirable feature of an index that is designed to capture the similarity in commuting patterns, because observing no inter-community flows for a pair of locations does not provide us with any information on the substitutability of these localities as places of residence.

Once we have obtained the similarity index s, it is straightforward to construct various forms of a refined contiguity matrix. Using a standard contiguity indicator such as

$$b_{ij} = \begin{cases} 1 & \text{if } i \text{ and } j \text{ are contiguous} \\ 0 & \text{otherwise} \end{cases} \tag{2}$$

(with $b_{ij} = 0$ if $i = j$), we define the elements of a first commuting-based $N \times N$ matrix

$W1$ as

$$w_{ij}^{(1)} = b_{ij}(1 - s_{ij}). \tag{3}$$

Of course, assuming a linear relationship between the weights and the similarity index for contiguous locations is not without alternatives. The elements of a matrix $W2$ that instead assumes a convex relationship are given by

$$w_{ij}^{(2)} = b_{ij}\, e^{-s_{ij}}(1 - s_{ij}). \tag{4}$$

Furthermore, one might also consider weights which account not only for commuting-patterns in terms of shares of outbound commuting going to other places, but also for the overall number of commuters. A matrix $W3$ can thus be constructed by multiplying the corresponding elements from $W1$ by the total number of commuters living in j and working in $k \neq i, j$,

$$w_{ij}^{(3)} = b_{ij}(1 - s_{ij}) \sum_{k \neq i,j} c_{jk}. \tag{5}$$

Finally, the elements of a matrix $W4$ are obtained by adjusting the weights given in Equ. (4) by the overall number of commuters from j,

$$w_{ij}^{(4)} = b_{ij}\, e^{-s_{ij}}(1 - s_{ij}) \sum_{k \neq i,j} c_{jk}. \tag{6}$$

By convention, each weight matrix is row-normalized.

As regards the potential endogeneity of the commuting-based matrices discussed above, it is worth noting that, although conceptually innovative, they are technically very similar to weight schemes which have been used extensively in previous work. If multiplied by an $N \times 1$ vector Y, representing, for instance, regional expenditures, our refined contiguity matrices will provide us with a vector of weighted averages of expenditures in contiguous regions. Hence, there is little reason to believe that our commuting-based matrices are more likely to be endogenous in a standard spatial model than contiguity or distance-based matrices that, for instance, inflate weights according to population figures as in studies like Brueckner (1998) or Brueckner and Saavedra (2001).

3 An application to expenditure competition among local jurisdictions

3.1 The empirical model

In the following, we apply the concept of refined contiguity matrices to the population of cities and townships in three U.S. states, namely Connecticut, Massachusetts, and Rhode Island. In particular, we employ the new matrices in a standard application of local public finance requiring such weights, namely the estimation of expenditure reaction functions, with local expenditures for police being the variable of interest. We then compare the outcomes of the spatial estimation procedure with the outcomes using standard contiguity weights.

To motivate the application, let us think of a population of local jurisdictions having some autonomy to collect local tax revenue (such as from taxing property) and to provide local public goods (such as policing). The objective of local governments is to ascertain the wants of their residents for public goods and to tax them accordingly. In equilibrium, every community will have achieved its optimal size in terms of the number of households or residents for which local public services can be produced at the lowest average cost. As noted by Tiebout (1956), if the number of jurisdictions is large, in such an equilibrium households in most communities will find that there is a set of jurisdictions offering a pattern that makes the respective places close substitutes to the household's actual place of residence.

Of course, exogenous shocks like changes in input prices or technology will affect the optimal amount of public goods provided by local governments as well as the optimal community size. To motivate the following empirical example, suppose that municipality A manages to increase its overall efficiency, enabling it to provide more public services while keeping taxes constant. This will make A more attractive relative to other places offering bundles of public goods which are close substitutes, eventually leaving these places with a suboptimal community size. To prevent households from moving to A, these close-substitute municipalities can be hypothesized to try to make up for the improved efficiency of public goods provision in A. On the other hand, the efficiency improvement in A will have little effect on jurisdictions offering a pattern that is no close substitute for A's own pattern.

In the following, we will consider police spending of the cities and townships in the sample discussed above. Given that public schooling is a responsibility of school districts and not municipalities, public safety is arguably the most important local public good provided by the local governments under consideration. Apart from the studies on expenditure and welfare competition mentioned in the introduction, the application is most closely related to work by Kelejian and Robinson (1992, 1993). Both studies are primarily concerned with theoretical issues related to testing and estimation in the presence of spatial interdependence and autocorrelation, but they also provide evidence on the determinants of county police expenditures. While Kelejian and Robinson (1992) consider only the case of spatial error correlation, Kelejian and Robinson (1993) find some evidence that police expenditures in a given county depend positively on lagged expenditures of contiguous counties. The authors note that this finding is consistent with the notion that "counties may strive in various ways to 'keep up with their neighbors'" (p. 308).

The expenditure equation that we are going to estimate takes account of the notion that police spending in reference municipalities might affect a municipality's own spending and reads

$$y_i = \alpha + \lambda y_{-i} + x_i \beta + u_i, \tag{7}$$

where y_i is municipality i's level of police spending per capita,[6] $y_{-i} = \sum_j w_{ij} y_j$ is the (weighted) average of spending for i's reference communities, x_i is a $1 \times K$ vector of community characteristics describing residents' wants for public safety as well as the ability of the local government to pay for this kind of service, and u_i is a residual. As control variables to be included among the characteristics x_i, we use population, the percentage of young and elderly residents, income per capita, and the property crime rate to capture variation in the local demand for policing, with positive coefficients expected

[6] We follow the convention to measure spending in per-capita terms, i.e. without taking logs (Kelejian and Robinson, 1992, 1993; Case et al, 1993; Baicker, 2005).

for all three variables. To account for differences in the ability to spend on local public goods, we also include total tax revenues per capita.

The parameters of Equation (7) are estimated using the spatial two-stage least square (2SLS) procedure suggested by Kelejian and Prucha (1998). It takes into account the endogeneity of y_{-i} by instrumental variables constructed as spatial lags of the exogenous characteristics x_i as well as spatial error correlation of the form

$$u_i = \rho \sum_j w_{ij} u_j + e_i, \tag{8}$$

where e_i is an i.i.d. residual.

The estimation procedure has three steps. The initial step consists of a simple 2SLS estimation ignoring spatial error correlation. Hence, we run a 2SLS regression on Equ. (7), treating y_{-i} as an endogenous regressor and selecting instruments from the set $x_{-i1}, \ldots, x_{-iK}$, where $x_{-ik} = \sum_j w_{ij} x_{jk}$ describes the (weighted) average of the kth characteristic from communities contiguous to i. In the estimations reported below, we restrict ourselves to using spatial lags of community population and the percentage of elderly people as instruments for y_{-i} because there is little reason to question the exogeneity of these two variables and they both turn out to be significant predictors of local police spending in our estimations. Since the crime rate is directly affected by policing,[7] we are well advised to treat it as an endogenous explanatory variable, too. As instrumental variables for the local property crime rate, we use the percentage of the population above age 15 separated or divorced as well as the percentage of the population below the poverty level, hypothesizing that both variables capture socially disruptive forces which can serve as exogenous predictors of the crime rate. By using these instruments, we impose the identifying assumption that local police spending directly depends on the crime rate but is related to the socially disruptive forces captured by the instruments only via the indirect effect working through crime. In a second step, a GMM procedure is used to estimate the parameter of the spatial error process, ρ, from the residuals of the initial estimation. The estimated coefficient of the spatial error process, $\hat{\rho}$ is then used to perform a Cochrane-Orcutt-type transformation of the estimation equation that

[7]See Levitt (2004) for a discussion of the related literature.

removes the spatial correlation from the residuals. In the third step, the vector of coefficients $\delta = (\alpha, \lambda, \beta')'$ is estimated from the transformed equation which, in matrix notation, reads

$$(I - \hat{\rho}W)Y = (I - \hat{\rho}W)(\alpha + \lambda WY + X\beta) + \epsilon. \tag{9}$$

Technically, the final step of the procedure is again a simple 2SLS estimation, using the same set of instruments as in the initial step after applying the transformation to these variables, too.

To derive the commuting-based weights for the 559 cities and townships in Connecticut, Massachusetts, and Rhode Island we take the information on place-to-place commuting flows at the level of Minor Civil Divisions from the 2000 census. Since we have selected only three states for our application, we consider not just the flows between the 559 communities covered, but also commuting originating from cities and townships in these states to municipalities in the remaining states. The reason is that our approach is based on the comparison of flows to all potential workplaces. Since, for instance, a considerable number of households living in Connecticut commutes to New York City, it is important to account for these flows when computing the weights for all pairs of contiguous municipalities in our sample.

Table 1 displays descriptive statistics on our data.

[Table 1 about here]

3.2 Results

The presentation of estimation results proceeds in two steps. First, we present and discuss a set of estimations using simple contiguity weights (Table 2). This provides us with a point of reference for the estimations using the refined matrices which take into account the degree of substitutability of cities and townships as places of residence (Table 3).

The first four columns in Table 2 report different specifications for our model of police expenditure. In all estimations, we use simple contiguity weights. The first thing to note is that the coefficient of spending of reference municipalities, λ, is remarkably stable across a number of different specifications regarding the control variables, ranging from 0.41 to 0.42. Moreover, the estimates for the spatial lag are significantly different from zero at the one percent level. Our estimations are thus well in line with the findings in previous studies on expenditure competition and spillovers from public goods provision (see the introduction for references). The coefficients of the control variables suggest that more populous municipalities and municipalities with a higher share of young and elderly people spend more on police per capita. Furthermore, we find that higher tax revenues fuel spending increases and that a higher rate of property crime is associated with more policing. All these findings conform to our expectations about the determinants of local police spending.

As regards the performance of the instruments, all diagnostic statistics (Hansen-test of over-identifying restrictions, F-statistic of instruments, Shea partial R^2 for both first-stage regressions) suggest that the instruments are strong and that the over-identifying restrictions cannot be rejected at any reasonable level of significance. At the bottom of the table we also report two tests of the spatial specification of our police expenditure model. The purpose of these exercises is to separately test the hypotheses $\lambda = 0$ and $\rho = 0$ using the robust Lagrange multiplier (LM) tests developed by Anselin et al. (1996). Since both tests are based on estimates under the null of $\lambda = \rho = 0$, they can be carried out using the results of simple OLS regressions. The test statistics (distributed $\chi^2_{(1)}$) and corresponding p-values reported under "LM test lag" refer to the test of the hypotheses $\lambda = 0$, whereas "LM test error" reports the test of the null $\rho = 0$. Across all specifications reported in Table 2, the robust LM tests indicate that using a model allowing for cross-sectional dependence in expenditures as well as spatial error correlation is appropriate. The last column in Table 2 displays the results for an estimation using a matrix assigning weights $w_{ij} = P_j$ to locations which are contiguous to i (where P denotes population) and a weight of zero to noncontiguous communities.[8] While all other findings are confirmed,

[8]As in all other cases, the matrix is row-standardized before estimation.

we obtain a significantly lower estimate for the spatial lag λ. With a point estimate of 0.25, the response of local governments to spending of contiguous municipalities is about 60% of the value obtained using the contiguity weights which are not adjusted according to community population.

[Table 2 about here]

Having evaluated the performance of the most commonly used contiguity weights, we can now turn to estimations using the refined weighting schemes. Table 3 reports eight estimations of our police expenditure model, the only difference in terms of specification between columns being the weight matrix employed in the estimation procedure. Before turning to the results for the spatial lag coefficient, we note that the previous findings regarding the performance of the instruments and the specification tests are confirmed across all estimations. In particular, the robust LM tests suggest that the (separately tested) hypotheses of no cross-sectional dependence in police expenditures and absence of spatial error correlation as specified in Equ. (8) are rejected at least at the five percent level of significance.

Column (1) displays the estimation results when using the weights from Equ. (3). Recall that these weights essentially capture the degree of similarity of commuting patterns originating from contiguous municipalities. Including the full set of control variables, we obtain an estimate for λ of 0.49, about 20% larger than in the reference estimation using simple contiguity weights (Column (4) from Table 2). Turning to Column (2), which employs the weight scheme from Equ. (4), we find that the point estimate changes only marginally, suggesting that the difference in how the similarity index s enters the weight formula is of no practical importance. Column (3) reports the findings when we make use of the weights from Equ. (5). Recalling that, apart from the pattern of commuting in terms of shares going to all other locations, the matrix $W3$ accounts for the overall number of commuters originating from contiguous municipalities, we note that this adjustment is very similar in nature to adjusting simple contiguity weights by the population of reference jurisdictions (as we did in Table 2, Column (4)). This notion is supported by the estimation outcome of 0.33 for the spatial lag, just 68% of the estimate from Column (1). Finally, as expected from the comparison of Columns (1) and (2), we do not find a significant difference between the point estimates obtained from schemes $W3$ and $W4$.

[Table 3 about here]

Although we have restricted the weights to attain positive values only for contiguous locations, in some applications a concern regarding the potential endogeneity of commuting-based weights could arise. In our application this would be relevant if households take into account the behavior of local governments in terms of police spending when making their choice on the housing market. Technically, this would result in the variable of interest, i.e. police spending, being determined simultaneously with commuting-based spatial weights, burdening the estimation of our model with an additional endogeneity problem. As we estimate the police expenditure equation using an instrumental variables approach, a straightforward way to further investigate the exogeneity of the weights is to check the validity of the instruments which are constructed as spatial lags of the municipality characteristics *population* and *% population > 65 years*. Given that there is little reason to question the exogeneity of these characteristics in our spending equation, a failure of the Hansen test to reject the overidentifying restrictions would suggest that the weights are exogenous. As can be seen from the bottom of the table, the p-values of the Hansen test indicate that the overidentifying restrictions cannot be rejected at any reasonable level of significance. This finding clearly supports the notion that in our application using contiguity weights adjusted for commuting patterns is acceptable.[9]

An alternative strategy to test for the exogeneity of the weights rests on using lagged data on place-to-place commuting flows for the derivation of weight matrices. Because community characteristics do change only gradually over time, historical commuting data should still provide us with sufficient information on the current degree of substitutability between locations, but historical decisions of households on the housing market (and, thereby, their commuting behavior documented in the corresponding data) should not

[9] The Hansen test also fails to reject instrument validity if we exclude the property crime rate from the regression and use as instruments only reference municipalities' population and reference municipalities' % population > 65 years.

depend on current policy decisions.

To see whether using historical commuting data makes any difference in our application, we report in Table 3, Columns (4) to (8), the same set of estimations as in the first four columns, with the only difference that we make use of commuting data from the 1990 census to derive the refined weight schemes $W1$ through $W4$. A quick inspection of the results reveals that in all four columns the estimates for λ are somewhat smaller than in their counterparts using current commuting data. While the differences are slightly more pronounced for the matrices $W3$ and $W4$, the general result is that our findings do not critically depend on whether current or historical commuting data are used for constructing the refined weight schemes. Moreover, the Hansen tests again fail to reject the exogeneity of the instruments. Under the assumption that lagged housing market choices do not depend on the current expenditure of local governments, we can conclude that in the current application there is no endogeneity problem with respect to the spatial weights of any practical importance.

4 Conclusion

The choice of a spatial matrix is critical in many empirical applications involving cross-sectional dependence. Unfortunately, the literature offers little guidance on how to choose an appropriate matrix. For applications in a Tiebout-like setting of local jurisdictions with households selecting a jurisdiction as a place of residence, the paper suggests a commuting-based refinement of the contiguity matrix as the most commonly used quantification of spatial association among locations. The concept rests on the idea to assign weights according to the degree of substitutability of communities as places of residence. By comparing commuting patterns and assigning large weights to contiguous communities which show a similar pattern of outbound commuting, we construct an index of the 'neighborliness' of jurisdictions capturing the degree of potential policy competition for a given set of residents.

To demonstrate the performance of various commuting-based refinements of the standard contiguity matrix, we estimate a model of expenditure competition among local jurisdictions. The example shows that the estimates for the cross-sectional dependence in expenditures obtained when using the refined weight schemes differ substantially from those obtained using a standard contiguity matrix.

While the idea to compare commuting patterns to derive spatial weights is limited to local jurisdictions such as cities, municipalities, counties, and school districts, the underlying principle can be applied quite generally. In studies of growth or international trade, for instance, one could use the patterns of international trade flows to derive spatial weight schemes. Such schemes could either be used to investigate issues like convergence, or one could use them to account for cross-sectional dependence in unobservables. Similarly, empirical work related to a wide range of issues from international tax and expenditure competition to cross-country correlation in the choice of regulatory regimes could benefit from an evaluation of trade patterns or foreign direct investment to determine countries which are likely to be points of reference for policy makers and other agents on the national stage.

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Table 1: Descriptive statistics for dependent and explanatory variables

	Mean	St. Dev.	Min	Max
Police spending	121	73.1	0.642	644
Population (× 1,000)	19.3	33.5	0.055	589
% population < 18 years	24.6	3.59	8.10	33.7
% population > 65 years	13.4	4.11	3.44	36.0
Income per capita (× 1,000)	29.1	9.94	11.2	84.8
Tax revenue per capita	1545	657	330	5912
Property crime rate (crimes reported per 1,000 residents)	20.4	18.5	1.54	222
% population > 15 years separated or divorced	10.0	2.69	3.83	20.6
% population below poverty level	5.76	4.37	0.666	30.6

Sample consists of cities and townships in Connecticut, Massachusetts, and Rhode Island (N=559). Sources: U.S. Census Bureau (Census of Governments 2002 and Census 2000 Summary File 3) and FBI Uniform Crime Report 2000.

Table 2: Spatial effects in municipalities' police spending – Simple contiguity weights

Dependent variable: Municipalities' police spending per capita					
Weighting matrix based on	Contiguity				Contiguity, pop.-weighted
	(1)	(2)	(3)	(4)	(5)
Spending of reference municipalities, y_{-i}	0.422***	0.415***	0.411***	0.409***	0.246***
	(0.100)	(0.108)	(0.096)	(0.101)	(0.073)
Population	0.616***	0.621***	0.660***	0.499***	0.529***
	(0.063)	(0.064)	(0.063)	(0.077)	(0.079)
% population < 18 years	0.766	0.647	0.178	1.60*	2.10**
	(0.780)	(0.831)	(0.777)	(0.877)	(0.964)
% population > 65 years	3.36***	3.32***	2.47***	2.38***	2.97***
	(0.705)	(0.715)	(0.695)	(0.734)	(0.823)
Income per capita	-	0.128	-	-0.070	0.072
		(0.287)		(0.414)	(0.432)
Tax revenue per capita	-	-	0.020***	0.017***	0.016***
			(0.004)	(0.006)	(0.006)
Property crime rate	-	-	-	1.33***	1.62***
				(0.357)	(0.370)
R^2	0.33	0.31	0.38	0.34	0.27
Hansen test (p-value)	0.92	0.96	0.48	0.21	0.63
F-statistic of IVs	87.1	82.1	90.7	25.2	29.6
Shea partial R^2 y_{-i}	0.24	0.23	0.25	0.24	0.44
Shea partial R^2 crime rate	-	-	-	0.15	0.18
LM test lag $\chi^2_{(1)}$ (p-value)	13.8 (0.00)	12.3 (0.00)	26.4 (0.00)	37.5 (0.00)	21.1 (0.00)
LM test error $\chi^2_{(1)}$ (p-value)	47.1 (0.00)	47.9 (0.00)	35.6 (0.00)	23.1 (0.00)	38.1 (0.00)

Sample consists of cities and townships in Connecticut, Massachusetts, and Rhode Island (N=559). Estimations account for spatial error correlation. Endogenous explanatory variables: spending of reference municipalities and property crime rate. Excluded instruments: reference municipalities' population, reference municipalities' % population > 65 years, % population > 15 years separated or divorced, % population below poverty level. Standard errors in parentheses. Significance levels: * 10%; ** 5%; *** 1%.

Table 3: Spatial effects in municipalities' police spending – Commuting-based contiguity weights

Dependent variable: Municipalities' police spending per capita

Commuting data from year	2000				1990			
Weight matrix	W1	W2	W3	W4	W1	W2	W3	W4
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Spending of reference	0.489***	0.502***	0.332***	0.351***	0.479***	0.485***	0.293***	0.300***
municipalities, y_{-i}	(0.095)	(0.095)	(0.074)	(0.080)	(0.096)	(0.097)	(0.071)	(0.072)
Population	0.465***	0.460***	0.589***	0.522***	0.460***	0.454***	0.539***	0.534***
	(0.080)	(0.081)	(0.070)	(0.078)	(0.080)	(0.082)	(0.076)	(0.077)
% population < 18 years	1.70**	1.71**	1.52*	2.06**	1.71**	1.72*	2.23**	2.25**
	(0.867)	(0.867)	(0.891)	(0.961)	(0.876)	(0.881)	(0.970)	(0.980)
% population > 65 years	2.26***	2.22***	2.79***	2.79***	2.35***	2.35***	3.00***	2.99***
	(0.719)	(0.718)	(0.760)	(0.802)	(0.729)	(0.733)	(0.818)	(0.821)
Income per capita	-0.004	0.028	-0.302	0.100	-0.002	0.028	0.061	0.095
	(0.387)	(0.388)	(0.371)	(0.413)	(0.392)	(0.395)	(0.414)	(0.417)
Tax revenue per capita	0.016***	0.016***	0.023***	0.017***	0.016***	0.016***	0.018***	0.017***
	(0.005)	(0.005)	(0.005)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Property crime rate	1.48***	1.51***	1.02***	1.67***	1.52***	1.57***	1.65***	1.69***
	(0.333)	(0.336)	(0.274)	(0.359)	(0.333)	(0.337)	(0.350)	(0.358)
R^2	0.39	0.40	0.27	0.27	0.37	0.37	0.25	0.25
Hansen test (p-value)	0.78	0.73	0.91	0.95	0.71	0.64	0.92	0.94
F-statistic of IVs	30.1	30.0	35.5	34.4	32.0	31.4	37.0	35.9
Shea partial R^2 y_{-i}	0.24	0.24	0.40	0.39	0.25	0.25	0.44	0.43
Shea partial R^2 crime rate	0.18	0.18	0.21	0.20	0.19	0.19	0.21	0.21
LM test lag $\chi^2_{(1)}$ (p-value)	50.2 (0.00)	54.3 (0.00)	31.8 (0.00)	34.4 (0.00)	45.8 (0.00)	49.3 (0.00)	26.6 (0.00)	26.4 (0.00)
LM test error $\chi^2_{(1)}$ (p-value)	9.66 (0.00)	4.71 (0.03)	19.7 (0.00)	13.8 (0.00)	10.8 (0.00)	5.29 (0.02)	24.7 (0.00)	21.0 (0.00)

Sample consists of cities and townships in Connecticut, Massachusetts, and Rhode Island (N=559). Estimations account for spatial error correlation. Endogenous explanatory variables: spending of reference municipalities and property crime rate. Excluded instruments: reference municipalities' population, reference municipalities' % population > 65 years, % population > 15 years separated or divorced, % population below poverty level. Standard errors in parentheses. Significance levels: * 10%; ** 5%; *** 1%.