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Using Spatial Econometric Techniques to Estimate Spatial Multipliers: An Assessment of Regional Economic Policy in Yucatán, Mexico*

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Abstract

Although the traditional economic base model remains a useful tool for regional analysis, in a multi-region context it fails to account for feedback effects. In addition, since the model is typically applied to individual regions, formal assessment of variation in the magnitude of regional multipliers is rarely considered. These shortcomings may be addressed by using spatial econometric techniques to model the economic base relationship stochastically. In this study, I incorporate spatial effects into the traditional economic base model and find empirical evidence that economic activity in Yucatán, Mexico generates indirect impacts not only locally, but among other locations that are linked economically. These spatial multipliers may be employed to estimate the potential spillover effects of economic activity and analyze the implications of regional economic policy.

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1. INTRODUCTION

Traditionally, the economic base model has been employed to estimate the overall impacts of regional export activity. Although the model remains a useful tool for regional economic impact assessment, in a multi-region context it fails to account for spillovers and feedback effects across locations. In addition, since the traditional model is typically applied to individual locations, formal assessment of variation in the size of regional multipliers is rarely considered. These shortcomings may be addressed, however, by using basic spatial econometric techniques to model the economic base relationship stochastically. Because spatial econometric techniques incorporate both spatial structure and spatial interaction, linkages among regions may be identified and resulting impacts can be quantified. Furthermore, as Mulligan and Gibson (1984) have shown, econometric techniques also provide a means of accounting for differences in the magnitude of economic base multipliers across locations.

In this study, I incorporate spatial effects into the traditional economic base model. The resulting spatial economic base model serves to estimate spatial multipliers, which quantify the geographic extent of economic impacts. In general, I find empirical evidence that economic activity generates employment not only locally, but among other locations that are linked economically. Furthermore, these spillover effects are associated with economic potential, which is a function of both complementarity (size of local economy) and transferability (distance). Section 2 discusses some of the conceptual issues associated with modifying the traditional economic base model in order to estimate spatial multipliers. Specification of a spatial weights matrix based on the concept of economic potential is discussed in Section 3. Subsequently, spatial econometric techniques are used in Section 4 to calibrate spatial economic base models. The case study presented in Section 5 provides empirical results of spatial multiplier models for 106 *municipios* in Yucatán, Mexico. The results of these models are used in Section 6 to estimate employment spillover effects and analyze the implications of regional economic policy in Mexico. Section 7 offers conclusions and identifies opportunities for further research.

2. CONCEPTUAL ISSUES

Richardson (1985) was among the first to suggest the need to incorporate space into economic impact analysis. However, in the intervening decade and a half, only a handful of scholars have attempted to move from traditional sectoral multipliers to more dynamic geographic multipliers (Olfert and Stabler 1999; Robison 1997; Sonis, Hewings, and Lee 1994; Haining 1987).

Spatial multipliers may be developed by using basic spatial econometric techniques to model the economic base relationship stochastically for a set of subregions (i) comprising a larger region (A). A nonspatial econometric approach to the economic base model was initially proposed by Mathur and Rosen (1972) in which basic economic activity at the regional scale is a function of economic activity in the “rest of the world.” During the past two decades Gordon Mulligan, in collaboration with numerous colleagues (Mulligan and Gibson 1984; Mulligan and Kim 1991; Vias and Mulligan 1997), has been at the forefront of attempts to establish an empirical and theoretical basis for the economic base model econometrically. This study

represents a modest attempt to build upon Mulligan's seminal work and incorporate space explicitly into the economic base model.

The traditional economic base model distinguishes between two kinds of economic activity – basic and nonbasic. As indicated in the identity below, total regional economic activity is merely the sum of basic and nonbasic components.

$$(1) \quad E_T = E_B + E_{NB}$$

where E_T refers to total economic activity, E_B indicates basic activity, and E_{NB} represents nonbasic activity.

Basic (or export) activities serve demands beyond the boundaries of the region. As Hewings (1985) states, these activities are derived from a combination of locational factors, comparative advantage, and historical accident. The second type of economic activity is termed nonbasic (or local). These activities serve demands within regional boundaries. The economic base model is premised on the fundamental assumption that nonbasic economic activity depends on basic activities. Mulligan and Gibson (1984) demonstrated empirically that a stable relationship exists between the size of the regional economy and the share of nonbasic economic activity. Consequently, nonbasic economic activity may be modeled econometrically as a function of total economic activity.

$$(2) \quad E_{NB} = \alpha + \beta E_T$$

where E_T and E_{NB} are defined as above, α represents an intercept term, and β represents the impact of a change in total economic activity on nonbasic economic activity.

The relationship between basic economic activity and total activity is specified by the economic base multiplier. In essence, the multiplier reveals the marginal impacts within the regional economy of a change in the basic sector. Since nonbasic activity is a stable proportion (k) of the regional economy, the base multiplier may be derived in the following fashion.

$$(3) \quad \begin{aligned} E_T &= (k)E_T + E_B \\ E_T &= E_B / (1 - k) \\ E_T &= (1 - k)^{-1} E_B \end{aligned}$$

Combining Equations 2 and 3, Mulligan and Gibson (1984) also established that the size of economic base multipliers (M) can be expected to increase in a nonlinear fashion as the size of the community becomes larger.

$$(4) \quad \begin{aligned} M &= (1 - k)^{-1} \\ k &= E_{NB}/E_T \text{ and } E_{NB} = \alpha + \beta E_T, \text{ so } k = (\alpha + \beta E_T)/ E_T \\ 1/M &= 1 - E_{NB}/E_T = 1 - (\alpha + \beta E_T)/ E_T \\ M &= 1/ (1 - \beta - \alpha/E_T) \end{aligned}$$

Equation 4 indicates that as total economic activity (as a surrogate for economic importance or size of the community) increases, the magnitude of the economic base multiplier can also be expected to increase, asymptotically approaching $1/(1 - \beta)$. Although the marginal propensity to sell locally remains constant, the base multiplier increases at a decreasing rate as E_T increases because the average propensity to sell locally increases as total economic activity becomes larger (Mathur and Rosen 1972; Mulligan and Gibson 1984).

Subsequent research (Mulligan and Kim 1991; Vias and Mulligan 1997) relies heavily on the concepts introduced above. However, in estimating sector and community-specific economic base multipliers for various functional types of small economies in the southwestern United States, Mulligan and colleagues have made numerous incremental improvements to the traditional model. Enhancements include incorporation of transfer payments, an increasingly important share of regional income (Kendall and Pigozzi 1994), and recognition that nonbasic employment in a given sector is driven not only by that location's basic employment, but also by nonbasic employment in all other sectors of the local economy.

Although the research cited provides empirical evidence of the theoretical economic base relationship, it fails to consider spatial effects explicitly. Mulligan and colleagues have worked with the Arizona community data set (ACDS), which provides detailed establishment-level data for relatively small communities. Data have been adjusted for in-commuters, and a 10-mile shadow area has been identified around each community. However, with secondary employment data at the county or township level typically used to estimate economic base models, errors may result when locations cannot be grouped to form discrete functional economic areas.

More recently, Smirnov (2000) incorporated space explicitly into the economic base model and established a somewhat different empirical foundation – he disaggregates basic economic activity into that which is exported to neighboring locations and that which is exported beyond neighboring communities. Using a spatial lags model, he links the local export base directly to export activities in neighboring communities. In general, he demonstrates that total economic activity at the county level in Texas is a function of exports to neighboring communities and globally beyond spatial neighbors.

Given the openness of local economies, the economic base multiplier may be recast by incorporating interaction among locations that make up the regional space economy. In essence, the traditional economic base model may be “expanded” as shown in Equation 5 below.

$$(5) \quad \begin{aligned} E_{Ti} &= E_{NBi} + E_{Bi} + W_{ij}E_{Tj} \\ E_{NBi} &= (rE_{Ti}) \\ E_{Ti} &= rE_{Ti} + E_{Bi} + W_{ij}E_{Tj} \\ E_{Ti} &= (1 - r)^{-1}[E_{Bi} + W_{ij}E_{Tj}] \end{aligned}$$

In the expanded economic base model proposed above, total economic activity within a particular sub-region (E_{Ti}) is a function not only of local basic sector activity (E_{Bi}), but also basic and nonbasic sector economic activity in other locations ($W_{ij}E_{Tj}$). The term W_{ij} expresses the propensity for economic activity in other locations (j) to create additional economic activity in location (i). In the context of spatial econometrics, W_{ij} is called a spatial weights matrix.

Specification of the spatial weights matrix used in the spatial economic base model of Yucatán's economy is discussed in the following section.

3. SPECIFICATION OF SPATIAL WEIGHTS MATRIX

According to Anselin and Bera (1998), spatial econometrics is comprised of a variety of techniques that deal with the peculiarities caused by spatial effects – distance, spatial interaction, and location, for example – in statistical models. Specifically, these techniques focus on two particular concerns – spatial dependence (spatial autocorrelation) and spatial structure (spatial heterogeneity).

Spatial econometric analysis relies on the specification of spatial weights matrices in order to quantify the impact of spatial structure on geographic (or economic) processes. Spatial weights matrices are typically based on relatively simple concepts such as contiguity, nearest neighbors, or inverse distance. However, some researchers have employed more elaborate concepts in specifying spatial weights, such as “economic distance” (Greenbaum 2002; Case, Rosen, and Hines 1993) and measures of trade flows (Aten 1997). Notwithstanding the type of spatial weights used, the choice of matrix must be appropriate for the research problem in question. As some scholars have noted (Anselin and Bera 1998; LeSage 1999), model results may be strongly influenced by the spatial weights matrix. In this study, a spatial weights matrix based on the concept of economic potential will be used to assess feedback effects among subregions. Specification of this “spatial-economic” weights matrix is detailed below.

Economic potential is a measure of accessibility and economic influence that indicates the likelihood for spatial interaction between locations (Taaffe, Gauthier, and O’Kelly 1996). The concept was introduced in the geographic literature by Harris (1954) and Warntz (1964). Several potential measures exist in the geographic literature; in all cases, the measures are based on the concepts of complementarity (economic importance) and transferability (distance) typically found in gravity models. In the context of this study, economic potential for a given subregion (*i*) is defined as follows.

$$(6) \quad V_i = \sum (P_j / d_{ij}^2)$$

where V_i refers to total potential, P_j represents economic importance (typically population or some other proxy for size) at place (*j*), and d_{ij}^2 is friction of distance or spatial separation between pairs of locations.

As defined above, economic potential is an aggregate measure that serves to quantify the relative accessibility of any given location (to other locations). However, as applied in this study, the economic potential for any dyad or pair of locations may also be calculated. In fact, based on Equation 6 above, the row sum of these dyads of economic potential for any given location (*i*) equals that location's total economic potential. This matrix of economic potential is easily calculated. If the row is standardized to equal 1, it may be used as a weights matrix – representing the structure of a regional space-economy – in order to apply spatial econometric techniques to the economic base model. An example is presented below to demonstrate how this “spatial-economic” weights matrix may be developed.

FIGURE 1
Hypothetical Study Area Comprised of Five Regions

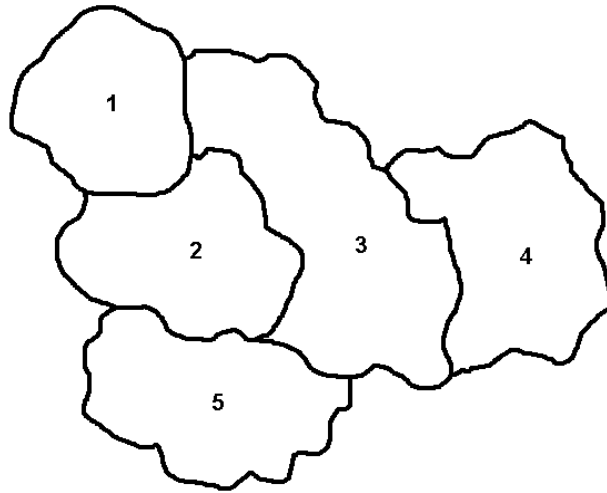


Figure 1 represents a simple hypothetical study area comprised of five regions. The equally simple and hypothetical data necessary to calculate economic potential for each location (population and distances between region centroids) are shown in Table 1.

Region 2 is the hypothetical equivalent of a primate city – the most populous and important location in the study area. In general, Regions 2 and 3 display the smallest aggregate distances to other locations. Consequently, due to its close proximity to the most populous location, Region 3 displays the greatest level of economic potential among the five locations. Region 2, although it is by far the most “economically important” location, possesses less economic potential because it is surrounded by relatively small neighbors.

As mentioned above, economic potential (V_i) for any given location is an aggregate measure of economic influence. Disaggregation of total economic potential for a particular region is a simple task, however, and is displayed in Table 2. This table reveals the relative importance of dyads or interaction between pairs of locations in accounting for a region's total economic potential. If this matrix is row standardized to sum to one, however, the relative weights assigned to each dyad change markedly (Table 3). Of particular note is the relative importance

TABLE 1
Hypothetical Data For Five Regions

Region	Population	d_{i1}	d_{i2}	d_{i3}	d_{i4}	d_{i5}	V_i
1	12	0.0	2.0	3.5	5.0	4.0	13.7
2	50	2.0	0.0	2.0	4.0	3.0	6.0
3	8	3.5	2.0	0.0	2.0	3.0	15.0
4	3	5.0	4.0	2.0	0.0	3.5	6.2
5	7	4.0	3.0	3.0	3.5	0.0	7.4

TABLE 2

Disaggregation of Economic Potential					
Region	1	2	3	4	5
1	0.0	12.5	0.7	0.1	0.4
2	3.0	0.0	2.0	0.2	0.8
3	1.0	12.5	0.0	0.8	0.8
4	0.5	3.1	2.0	0.0	0.6
5	0.8	5.6	0.9	0.2	0.0

of Region 2 with respect to other locations in the study area – due to its economic importance, this location accounts for more than 50 percent of total economic potential in each of the remaining zones.

The spatial-economic weights matrix shown in Table 3 may be employed in analogous fashion to more traditional spatial weights matrices. Essentially, the matrix based on the concept of potential includes not only the impact of proximity and spatial separation (as in customary weights matrices), but also an indication of relative economic importance. Conceptually, therefore, this matrix may be thought of as a combination of two kinds of weights: inverse distance and relative position in a central place hierarchy (economic importance). Furthermore, the weights matrix displays two other important properties for spatial econometric analysis: diagonal elements are zero (a general convention), and the matrix is specified exogenously.

Spatial-economic weights may be compared to a traditional weights matrix based on contiguity (Table 4) to emphasize differences between the two approaches. Region 3 provides a good example of relevant differences in spatial weights. Based on simple contiguity, each neighbor exerts a similar effect on this location (0.25 each). However, the spatial-economic weights matrix (Table 3) suggests that the impact of each neighbor will vary greatly and that this influence will depend on each region's economic importance as well as distance.

These differences may be highlighted further by examining a hypothetical spatial autoregressive (SAR) process with a spatial correlation parameter (ρ) of 0.25. The general form of the SAR model may be stated as:

$$(7) \quad y = \rho W y + X \beta + \varepsilon$$

where y is an $n \times 1$ vector corresponding to the dependent variable, W represents the spatial weights matrix, ρ is the spatial correlation parameter, X is an $n \times k$ matrix of independent variables, and ε represents model residuals. The resulting spillover effects may be estimated in matrix form as $(I - \rho W)^{-1}$. Tables 5 and 6 display spillover effects (with $\rho = 0.25$) based on both simple contiguity and economic potential.

The differences between the two matrix specifications are readily apparent. In the case of the weights matrix based on simple contiguity, Region 3 generates the largest spillover effects in each of the remaining zones. However, the contiguity matrix captures only the geographic relationship between locations. As indicated in Table 1, Region 3 is much smaller and hence much less economically important than Regions 1 and 2. The alternative matrix specification based on economic potential accounts for both geographic and economic relationships. Thus,

TABLE 3

Spatial-Economic Weights Matrix					
Region	1	2	3	4	5
1	0.00	0.91	0.05	0.01	0.03
2	0.50	0.00	0.34	0.03	0.13
3	0.07	0.83	0.00	0.05	0.05
4	0.08	0.51	0.32	0.00	0.09
5	0.10	0.75	0.12	0.03	0.00

TABLE 4

Traditional Spatial Weights Matrix Based on Simple Contiguity

Region	1	2	3	4	5
1	0.00	0.50	0.50	0.00	0.00
2	0.33	0.00	0.33	0.00	0.33
3	0.25	0.25	0.00	0.25	0.25
4	0.00	0.00	1.00	0.00	0.00
5	0.00	0.50	0.50	0.00	0.00

TABLE 5

Spatial Lag Effects Based on Simple Contiguity

Region	1	2	3	4	5
1	1.020	0.139	0.144	0.009	0.020
2	0.092	1.030	0.110	0.007	0.092
3	0.072	0.083	1.041	0.065	0.072
4	0.018	0.021	0.260	1.016	0.018
5	0.020	0.139	0.144	0.009	1.023

TABLE 6

Spatial Lag Effects Based on Economic Potential

Region	1	2	3	4	5
1	1.032	0.246	0.034	0.005	0.017
2	0.136	1.058	0.092	0.010	0.037
3	0.046	0.229	1.022	0.015	0.021
4	0.042	0.162	0.096	1.003	0.030
5	0.053	0.212	0.049	0.011	1.008

Region 2 generates the largest spillover effects in all instances.

In summary, then, development of a truly spatial economic base model requires components of both proximity and economic importance in order to account for potential spillovers between regions. In essence, the magnitude of feedback effects among locations should depend not only on relative location but also functional economic relationships.

4. CALIBRATION OF SPATIAL ECONOMETRIC MODELS

In order to calibrate spatial economic base models, basic and total economic activity must be estimated for each of the subregions (*i*) making up a larger region (*A*). As discussed in more detail in Section 5, subregions are defined as the 106 *municipios* comprising the state of Yucatán, Mexico (Figure 2). The traditional location quotient (LQ) approach will be applied to sectorally disaggregate employment data (at the three-digit NAICS level) from the 2000 Census of Population to estimate basic and total employment at the *municipio* level. The basic formula for the LQ method is shown below.

$$(8) \quad LQ_i^s = \frac{\left(\frac{E_i^s}{E_i}\right)}{\left(\frac{E_A^s}{E_A}\right)}$$

where *E* refers to employment, (*i*) refers to a given *municipio*, (*s*) refers to a particular sector or industry, and *A* refers to the state of Yucatán.

In essence, the location quotient is simply the ratio of two ratios. The numerator expresses the percentage of the workforce employed in a given sector for a particular *municipio*. The denominator displays the same relationship at the state level. If the percentage of the workforce employed in a given sector at the *municipio* level exceeds the state average, the location quotient will be greater than 1. If the LQ is greater than 1, it is assumed that the *municipio* is self-sufficient and that “excess” employment serves demand outside the region. If the LQ is less than 1, it is assumed that the *municipio* is not self-sufficient and that no basic employment exists. Although this approach has its limitations, its use remains common in the literature and applied research (Isard et al. 1998). The LQ must be carried out and summed over all sectors for each of Yucatán's *municipios* in order to derive estimates of basic and nonbasic employment for each location.

Subsequently, census data on transfer payments (pensions and other private and government transfers) will be converted to full-time equivalent employment and included in the spatial econometric model to ensure that the economic base model does not over-predict multiplier effects. As Vias and Mulligan (1997) suggest, full-time equivalent employment may be estimated by dividing total transfer payments for a given community by average annual income. Adjusted economic base multipliers for Yucatán are displayed in Figure 2. In general, the largest economic base multipliers are found in and around the capital city, Mérida. Several large peripheral *municipios*, including Tizimín and Valladolid along Yucatán's eastern border, also display relatively large multipliers.

Following estimation of economic base model components and specification of spatial weights, the next step in modeling the economic base relationship econometrically is calibration of a traditional OLS model. Total employment serves as the dependent variable; basic employment and transfer payment employment are used as independent variables. The traditional OLS model is specified as follows.

$$(9) \quad \ln(E_T) = \alpha + \beta_1 \ln(E_B) + \beta_2 \ln(E_{TP}) + \varepsilon$$

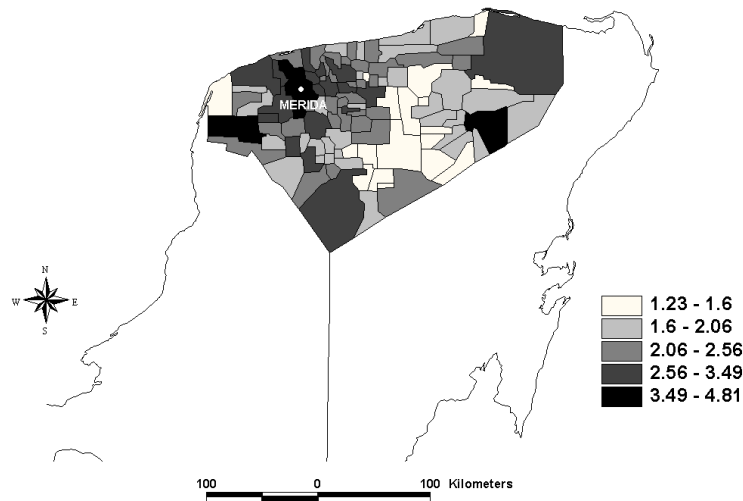
where E_T and E_B are defined as above, E_{TP} represents full-time equivalent employment resulting from transfer payments, α is a constant or y -intercept term, β_1 and β_2 are regression coefficients accounting for the economic base relationship, and ε represents the error term.

As indicated in Equation 9, variables have been log transformed to account for heterogeneity (and likely heteroskedasticity). Furthermore, since the economic base relationship is nonlinear (Mulligan and Gibson 1984), the double-log functional form allows estimation of individual spatial multipliers for each subregion (i) by taking the anti-log of variables and using model coefficients to calculate individual slope parameters (Studenmund 1992):

$$(10) \quad EBM_i = \beta_1 \left(\frac{E_T^i}{E_B^i} \right).$$

This initial model will be used not only to estimate the relationship between total economic activity (dependent variable), basic activity and transfer payments (independent variables), but also to carry out diagnostics for spatial effects on variables and residuals. For the sake of comparison, diagnostic tests will be performed using a traditional spatial weights matrix based on simple contiguity as well as the weights matrix specified on the basis of economic potential. Assuming spatial effects are present, spatial regression techniques will be employed to correct the model and obtain unbiased, consistent estimates of model parameters. In addition, incorporation of spatial effects will facilitate identification of spillovers among *municipios* and account for the varying magnitude of economic base multipliers.

FIGURE 2
Adjusted Economic Base Multipliers – Yucatán, Mexico (2000)



Results of the diagnostic tests mentioned above will determine what kind of spatial econometric model best represents the economic base relationship at the *municipio* level in Yucatán. In general, four possible model outcomes exist: no spatial effects, spatial lag effects, spatial error effects, and a combination of spatial lag and spatial error effects. Each of these potential outcomes is discussed below.

In the event of no spatial effects, the simple OLS model above (Equation 9) may be employed to represent the economic base relationship at the local scale in Yucatán. In this instance, no spatial autocorrelation will be found among model residuals. As with all econometric models, however, issues of heteroskedasticity and non-normality of residuals must be taken into account.

Spatial lag effects are present in OLS models when a substantive process (spatial interaction, for example) brings about autocorrelation in model residuals (Anselin 1988). From a theoretical perspective, the spatial economic base model is premised on the existence of spatial lag effects, as economic activity in one *municipio* is expected to generate indirect economic activity in other *municipios*. Since spatial interaction (spillover effects) is associated with both relative location and economic importance, a weights matrix based on the concept of economic potential will be used. The spatial lags model may be specified as follows.

$$(11) \quad \ln(E_T) = \alpha + \rho W_P \ln(E_T) + \beta_1 \ln(E_B) + \beta_2 \ln(E_{TP}) + \varepsilon$$

where E_T , α , E_B , E_{TP} , and ε are defined as above; W_P represents the spatial weights matrix based on economic potential; β_1 and β_2 represent the direct impacts of basic activity and transfer payments within the *municipio*, respectively; and ρ corresponds to indirect (or feedback) impacts of economic activity in other *municipios*.

In this model, inclusion of a spatially lagged variable eliminates spatial dependence among the error terms. Failure to include the spatially lagged variable is tantamount to specification bias due to omitted variables; parameter estimates will be biased and inconsistent. Furthermore, spatial lags models will be calibrated with maximum likelihood estimation since the autoregressive component of the model is correlated with residuals and traditional OLS does not yield consistent estimates (Anselin and Bera 1998).

The spatial lags model is analogous to a (mixed) autoregressive model in time-series analysis and offers a theoretically sound, intuitive approach for modeling spatial multiplier effects among *municipios* in Yucatán. The initial independent variables $\ln(E_B)$ and $\ln(E_{TP})$ capture the “intra-regional” impacts of basic activity within the region on total regional employment. The lagged dependent variable, $\rho W_P \ln(E_T)$, captures the “inter-regional” or spillover impacts of economic activity in other locations on total employment within a given *municipio*. In general, ρ is expected to take a value somewhere between 0 and 1.

According to Anselin and Bera (1998), spatial error effects are a form of “nuisance dependence” in the residuals that frequently results in geographic data when administrative boundaries (used for data collection) do not coincide with the substantive process being modeled.

Consequently, a spatial weights matrix based on relatively simple concepts such as contiguity or nearest neighbors is typically used in spatial error models.

Although OLS estimation in the presence of spatial correlation among model residuals yields unbiased coefficients, estimates of standard errors will be inconsistent. In addition, inferences based on F and t -statistics will be misleading and the coefficient of determination (R^2) will be incorrect (Greenbaum 2002). Consequently, the spatial errors model is also estimated using maximum likelihood techniques and takes the following form.

$$(12) \quad \ln(E_T) = \alpha + \beta_1 \ln(E_B) + \beta_2 \ln(E_{TP}) + \lambda W_C u + \varepsilon$$

where E_T , α , E_B , E_{TP} , β_1 , and β_2 are defined as above; W_C is a spatial weights matrix based on simple contiguity; u represents the spatially correlated component of the residuals; λ is an autoregressive error parameter; and ε is a normally distributed, uncorrelated error term.

The possibility exists that both spatial lag and spatial error effects will be present in OLS residuals simultaneously. In the case of the spatial economic base model, existence of both forms of spatial dependence is quite plausible. On the one hand, spatial error effects may exist because political boundaries do not necessarily reflect actual labor market boundaries. On the other hand, spatial lag effects may result if economic activity in a given location is affected by economic activity in other locations.

The combined spatial lags and spatial errors model has been termed SARMA (spatial autoregressive moving average) by Cliff and Ord (1981); it may also be estimated via maximum likelihood and can be expressed as follows.

$$(13) \quad \ln(E_T) = \alpha + \rho W_P \ln(E_T) + \beta_1 \ln(E_B) + \beta_2 \ln(E_{TP}) + \lambda W_C u + \varepsilon$$

where all variables and parameters are defined as above. In practice, as Anselin and Bera (1998) and LeSage (1999) note, the spatial weights matrix used in the lag component of the model usually differs from the matrix used in the error component. Conceptually, at least in the case of the spatial economic base model, the weights matrix derived from the concept of economic potential (W_P) may be used to test the spatial lag relationship; spatial weights based on simple contiguity (W_C) may be employed in the spatial error component of the model.

5. CASE STUDY AND EMPIRICAL RESULTS

As Figure 2 reveals, the state of Yucatán, Mexico, is located at the crown of the peninsula that bears its name. The state is comprised of 106 *municipios*, roughly equivalent to U.S. counties. At present, Yucatán's population is about 1.7 million; about 40 percent of all inhabitants, one-half of total employment, and 75 percent of gross state product are concentrated in the capital city and *municipio* of Mérida (INEGI 2000). Consequently, average per capita income in Mérida is roughly four times greater than in rural areas of the state (Biles 2001).

A recent policy initiative, the *1995-2001 State Development Plan*, identified the excessive concentration of economic activity in Mérida as the primary cause of disparities in income,

employment, and economic opportunity in Yucatán (*Estado de Yucatán* 1996). In response, policymakers proposed channeling industrial activity to rural areas of the state to promote a more equitable spatial distribution of employment, redress disparities, and achieve “balanced sustainable regional development.” In this section, the spatial econometric models discussed above will be used to estimate spatial multipliers. In Section 6, spatial multipliers will be employed to analyze the implications of regional economic policy in Yucatán. Specifically, policy analysis will focus on identifying the geographic distribution of economic impacts and the likelihood of generating “spillover” economic activity in rural areas of the state.

As indicated above, the basic OLS model specified in Equation 9 must be estimated initially. Not surprisingly, basic employment and transfer payments account for more than 94 percent of the variation in total employment at the *municipio* level (Table 7). However, the initial OLS model has been carried out primarily for diagnostic purposes. The Jarque-Bera test ($p = 0.811$) reveals that model residuals are normally distributed, and the Breusch-Pagan test ($p = 0.623$) indicates lack of heteroskedasticity among the error terms. More importantly, the Moran’s I statistic reveals statistically significant spatial dependence among residuals based on both contiguity ($I = 0.380$) and economic potential ($I = 0.120$) weights matrices. Lagrangian multiplier tests confirm the presence of highly significant spatial error effects, based on simple contiguity, and spatial lag effects, based on economic potential ($p < 0.000$ in both instances).

Since diagnostic tests indicate that spatial error effects are most statistically significant, a spatial errors model should be calibrated. If spatial autocorrelation persists following estimation of the spatial errors model, an alternative specification must be sought. The results of the spatial errors model are shown in Table 7.

As mentioned above, maximum likelihood estimation must be used to calibrate the spatial errors model since traditional OLS does not yield consistent estimates. In general, the overall goodness of fit of the spatial errors model as well as the statistical significance of independent variables is strong. The coefficient corresponding to basic employment does not change significantly. However, the parameter for transfer payments increases slightly, though it takes the expected sign and its statistical significance improves somewhat (Table 7).

Importantly, the coefficient corresponding to the spatial errors parameter (λ) proves highly statistically significant. Therefore, we may conclude that some degree of spatial mismatch exists in the traditional (nonspatial) econometric specification of the economic base model – political boundaries do not adequately reflect actual labor market boundaries at the *municipio* level in Yucatán. Although this result is significant (and important), it is hardly surprising since a large share of the population lives and works in different locations. Although the model successfully accounts for spatial error effects, Lagrangian multiplier tests on the weights matrix based on economic potential indicate the persistence of spatial lag dependence. Consequently, a combined model with spatial error and spatial lag terms may be estimated.¹

¹ As stated above, the basic spatial errors models failed to eliminate spatial lag dependence. Although not shown, a basic spatial lags model failed to eliminate spatial error dependence. Hence, the combined model with spatial lag and spatial error components was implemented.

TABLE 7

Parameter Estimates for Spatial Multiplier Models

Variable	OLS model		Spatial Errors Model		SARMA Model	
Constant	0.305	(0.197)	0.285	(0.177)	-0.705	(0.374)
$\ln(E_B)$	1.022**	(0.053)	1.014**	(0.048)	0.990**	(0.048)
$\ln(E_{TP})$	0.092*	(0.050)	0.106**	(0.043)	0.127**	(0.043)
λ			0.581**	(0.102)	0.423**	(0.122)
ρ					0.109**	(0.036)
Adj./Pseudo R ²	0.943		0.957		0.958	
F-statistic	852.022**					
Likelihood			10.584		13.779	
LM Error (contiguity)	36.669**				2.830	
LM Lag (potential)	20.294**		4.737*			

Note: Dependent variable in all models is $\ln(E_T)$. Standard errors are shown in parentheses. * indicates statistical significance at $\alpha = 0.05$; ** indicates statistical significance at $\alpha = 0.01$

Following Greenbaum (2002) and LeSage (1999), the combined spatial errors and spatial lags model is also estimated using maximum likelihood techniques. The overall model and coefficients corresponding to basic employment, transfer payments, and the spatial error term remain highly statistically significant (Table 7). In addition, the magnitude of these coefficients experiences only modest changes. The coefficient corresponding to the spatial lag parameter (ρ) displays the expected sign (+) and magnitude ($0 < \rho < 1$) and proves statistically significant at the 99-percent confidence level.

In general, the model indicates that a one percent increase in basic employment generates slightly less than a one percent increase in total employment; a similar change in transfer payment employment generates only a 0.127 percent change in total employment. The magnitude of the coefficient corresponding to basic employment ($\beta_1 < 1$) suggests that the traditional economic base model slightly overstates multiplier effects. Based on the statistical significance of (ρ), it may be inferred that the nonspatial economic base model fails to account for spillover activity in other locations and attributes “inter-regional” employment generation effects to “intra-regional” basic employment.

Consequently, we may conclude that economic activity in a given *municipio* does indeed generate indirect economic impacts in other locations. Furthermore, based on the “spatial economic” weights matrix specified above, spillover effects are associated with economic potential, which is a function of both distance and economic importance.

In general, SARMA model residuals are somewhat smaller and less geographically clustered than those of the basic OLS model. Lagrangian multiplier tests confirm that no significant spatial autocorrelation remains in error terms based on simple contiguity and residuals are homoskedastic ($p = 0.722$). Normality of residuals was not assessed since maximum likelihood estimation requires the assumption that model error terms are normally distributed. Since no significant spatial dependence remains in residuals, no alternative spatial econometric models

need be calibrated. As a consequence, the spatial lags component of the SARMA model specified above may be used to estimate the spatial economic base relationship at the *municipio* level in Yucatán.

6. POLICY IMPLICATIONS

As indicated in Section 3, the spatial lags component of the spatial economic base model may be expressed in matrix terms as $(I - \rho W)^{-1}$. Since the value of ρ above is less than 1 and the spatial weights matrix has been row standardized (to equal 1), the spatial lag component of the model may be envisioned as a “Leontief inverse” in order to estimate direct and indirect spatial multiplier effects (Anselin and Bera 1998).

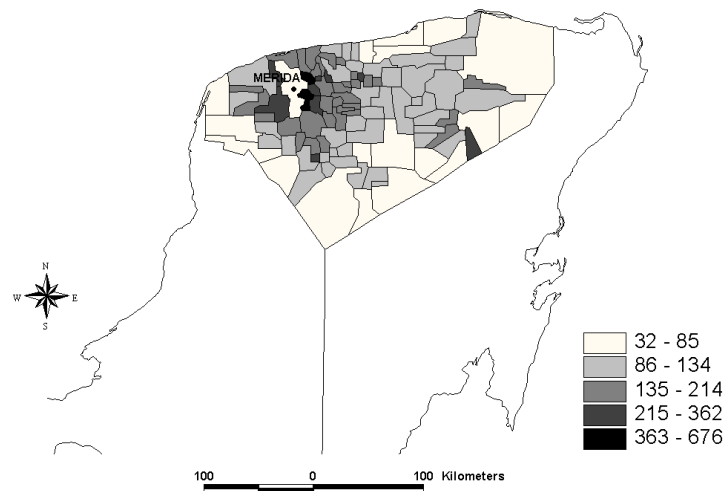
Using the spatial multiplier component of the SARMA model, the geographic distribution of spillover economic activity may be estimated at the *municipio* level in Yucatán. For any *municipio* (i), the spatial multiplier (EBM*) is simply defined as the sum of total spillovers created in all locations (j) by economic activity in (i) divided by total economic activity in (i):

$$(14) \quad EBM_i^* = \sum E_{ij} / E_i .$$

As shown in Figure 3, it is possible to visualize aggregate spatial multipliers for each of Yucatán’s 106 *municipios*. In general, locations bordering Mérida produce the strongest feedback effects. For example, every 1,000 jobs in the neighboring *municipio* of Kanasín generate almost 680 additional employment opportunities in other locations. Not coincidentally, more than 50 percent of these impacts are concentrated in the state capital.

FIGURE 3

Aggregate Spatial Multipliers at the Municipio Level in Yucatán (Per 1,000 Jobs)



In the case of Mérida, spatial multiplier effects are far more constrained. In general, every 1,000 jobs in the state capital produce fewer than 60 employment opportunities in other *municipios*. These results corroborate the strongly asymmetric functional economic relationship between a primate city and its hinterlands and suggest that a regional policy aimed at concentrating economic activity in rural areas of Yucatán may have limited success because spillover effects are disproportionately concentrated in the state capital.

In addition, it is possible to disaggregate spatial multipliers to identify the destination of any given location's spillover effects. Four representative examples are offered in Figures 4-7 to illustrate the distribution of spatial multiplier effects.

Figure 4 displays the distribution of spatial multiplier effects of economic activity in Mérida. Overall, due to its overwhelming economic importance (more than 280,000 jobs), employment in the state capital creates more than 16,000 spillover jobs in other *municipios*. More than 500 additional jobs are created in six locations, including indirect feedback effects that reverberate back to Mérida. In general, Mérida's spatial multiplier effects are largely concentrated in the western half of the state; spillover economic activity generated by the state capital accounts for two to five percent of total employment in most locations.

Figure 5 displays the spatial multiplier effects for the port city of Progreso, located about 30 kilometers north of Mérida. Overall, economic activity in Progreso generates more than 3,300 employment opportunities throughout the state. However, about 80 percent of all feedback effects accrue within Mérida. Additional impacts are geographically diffuse; in general, however, the most prominent spillover effects are concentrated in relatively large *municipios* and in close proximity to Mérida.

FIGURE 4

Destination of Spatial Multiplier Effects (Mérida)

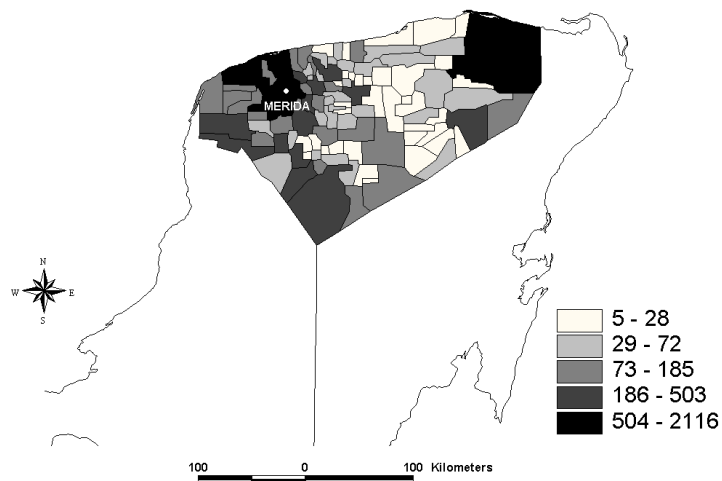
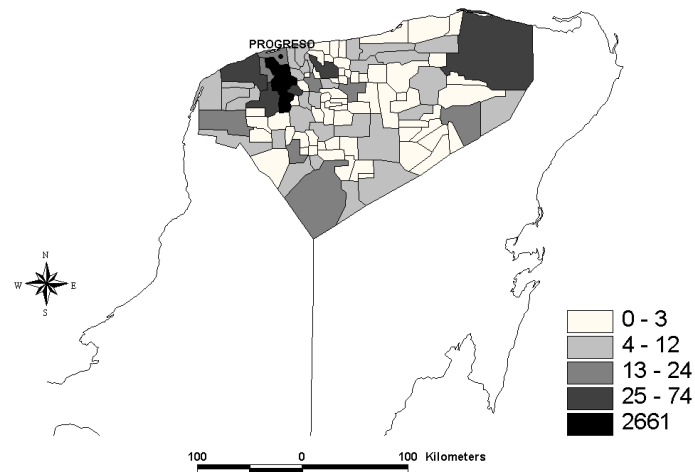


FIGURE 5
Destination of Spatial Multiplier Effects (Progreso)



The distribution of spatial multiplier effects for Izamal, a representative town in Yucatán's interior are displayed in Figure 6. Feedback effects amount to more than 800 jobs; about one-third of spillovers occur in Mérida. Remaining impacts are concentrated in the central part of the state and among a handful of *municipios* along Yucatán's southern and eastern borders.

The spatial multiplier effects for Valladolid, a relatively large *municipio* in eastern Yucatán, are shown in Figure 7. Overall, economic activity in this *municipio* generates almost 1,400 additional employment opportunities throughout the state. Relatively speaking, economic activity in Valladolid generates the most geographically diverse and balanced impacts. However, with the exception of Mérida (less than seven percent of total jobs created), feedback effects are highly concentrated in the eastern part of the state. In particular, the nearby *municipios* of Tizimín (north) and Chemax (east) account for almost 40 percent of spillover employment.

In general, the examples presented provide some insights into the implications of regional economic policy in the case of Yucatán. Channeling economic activity to Mérida or nearby locations (such as Progreso) is unlikely to reduce disparities and promote more balanced regional development. As Figure 6 attests, concentration of economic activity in fairly distant *municipios* (such as Izamal) still results in a relatively unequal spatial distribution of benefits. The final example, however, suggests that a greater geographic balance in regional development might be obtained by concentrating additional economic activity or establishing growth poles in peripheral locations such as Valladolid.

FIGURE 6
Destination of Spatial Multiplier Effects (Izamal)

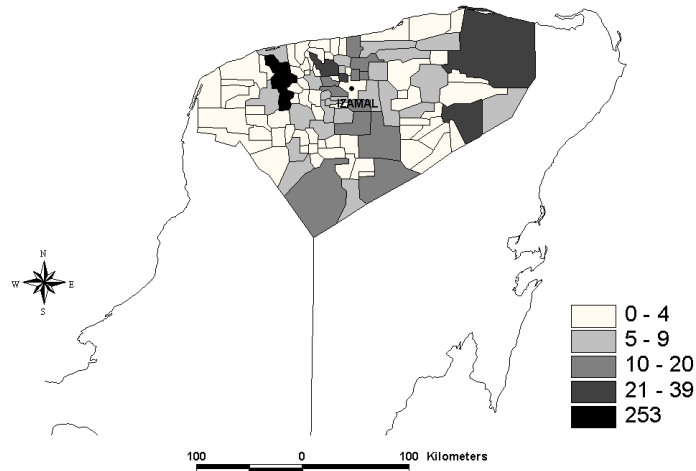
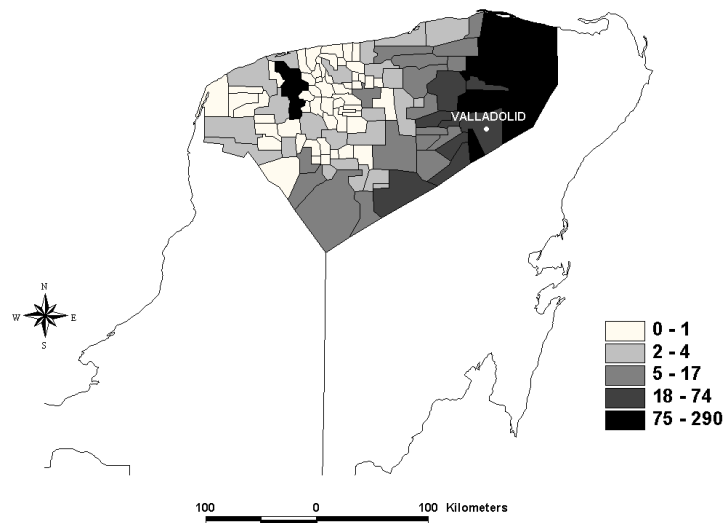


FIGURE 7
Destination of Spatial Multiplier Effects (Valladolid)



7. CONCLUSIONS AND OPPORTUNITIES FOR FURTHER RESEARCH

In general, the empirical results above support the conceptual issues introduced in Sections 2, 3, and 4. The economic base relationship for a set of subregions (i) may be modeled successfully by using basic spatial econometric techniques. In addition, at least in the case study presented

above, a spatial weights matrix based on the notion of economic potential accounts for spatial lag effects in the residuals of the traditional OLS model. Furthermore, the spatial econometric model calibrated with both spatial error and spatial lag components facilitates estimation of spatial multiplier effects, which may be used to assess the implications of regional economic policy in Yucatán, Mexico. Spatial multiplier models also corroborate intuitive understanding of the Yucatán's space economy – recent policy initiatives are unlikely to have much success in promoting “balanced” regional development since spillover effects are disproportionately concentrated in Mérida, the state capital.

Notwithstanding these initial results, further research is needed on several fronts. On the one hand, secondary data at the *municipio* or county level probably mask as much spatial interaction as they reveal. Consequently, a need exists for spatial economic base analysis at a more detailed geographic scale. Furthermore, at least in the case of Yucatán, more extensive geographic coverage is also needed. Therefore, subsequent versions of this model should include detailed information on economic activity for the entire Yucatán Peninsula (including the neighboring states of Campeche and Quintana Roo).

Another possible research area concerns the specification of alternative spatial weights matrices. Although spatial weights based on economic potential adequately accounted for spatial lag effects in the model calibrated above, a different weights matrix may be more representative of Yucatán's regional economic structure. Preliminary exploratory spatial data analysis indicated no statistically significant spatial lag effects based on inverse distance weights once spatial error effects had been removed. Consequently, an alternative weights matrix that captures a location's relative position (and functional linkages) within the regional central place hierarchy may be more representative of Yucatán's space-economy.

Finally, the traditional economic base model is essentially a two-region, two-sector model that treats the local sectors of each region as autonomous entities. The spatial multiplier concept introduced above accounts for spillover and feedback effects among locations in a multiregion context. It is necessary, however, to expand the sectoral detail of the spatial economic base model in order to provide a more realistic estimate of the geographic extent of economic impacts. Furthermore, the spatial multiplier models calibrated presume that spillover effects, as represented by (ρ), are constant across space. Additional research is needed to assess spatial variation in the magnitude of feedback effects and the possibility of estimating spatial lag parameters for individual locations.

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