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SPATIAL EFFECTS OF HIGHWAYS ON EMPLOYMENT IN MISSOURI

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Keywords
employment, highway, spatial lag model, Missouri

Abstract
The purpose of this paper is to determine if there is a relationship between highway development and the spatial pattern of employment growth in Missouri. In order to determine if there is a spatial pattern to the employment growth in the county, a spatial lag model was estimated and contrasted with a simpler model that did not consider spatial relationships. My intention is to figure out how highways in a county and neighboring counties affect the employment of that county. Interstate highways in Missouri are shown not to have positive effects on employment growth. The "mileage of four-lane roads in a county" variable has significant and negative effects on employment growth. The "number of miles of two-lane roads within a county" variable has an insignificant and negative effect. In addition, "two lane road mileage in surrounding counties" has insignificant and positive effects. The spatial autoregressive coefficient (ρ) is significantly positive, implying that there is a positive spatial interaction between the counties. Results suggest that road networks that are too dense can have negative impacts on employment growth in a county, and that highway overinvestment may lead to diminishing employment returns in Missouri.

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I. Introduction

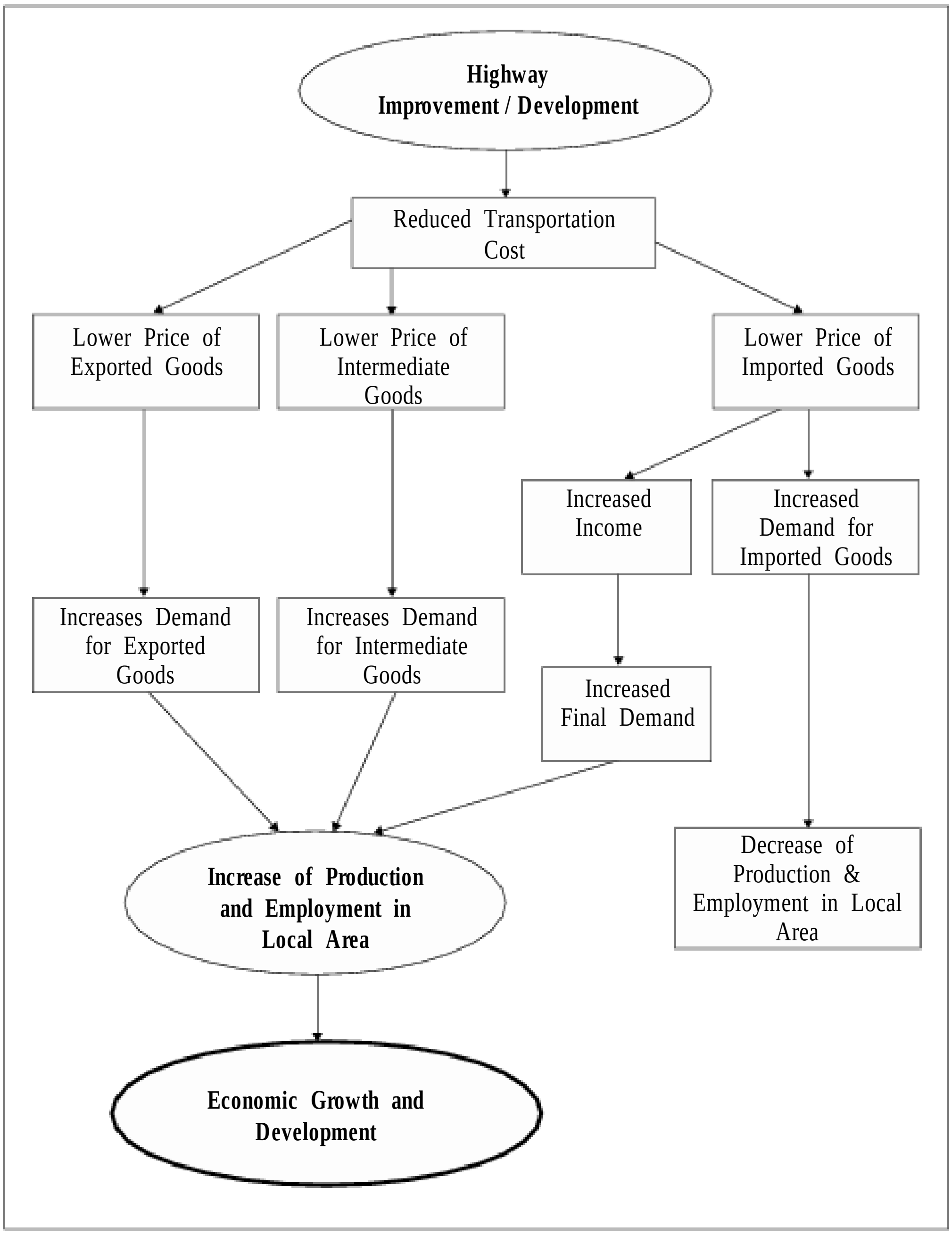
We can consider highway improvements as an important factor in developing the regional economy. The better highway systems make production and distribution efficient, and have positive effects on economies of scale, specialization, and cost reduction (Jiang, 2001). David A. Aschauer (1989), Alica H. Munnell (1990), and M. Ishaq Nadiri and Theofanis P. Mamuneas (1996) found that public capital has important contributions to output and economic growth.

State highway investment projects are often justified on the grounds that such efforts will have positive economic impacts. In particular, road network improvements are considered useful means of bringing development to undeveloped areas, including rural areas. Transportation routes are often promoted as support for commerce in the U.S. For rural areas experiencing economic distress, such policies are often welcomed with open arms by residents. Empirical evidence suggests that there is a close relationship between the presence of infrastructure (i.e., highways) and economic development. In general, however, evidence is less certain as to whether road investments play a specific role in the economic growth of rural areas specifically.

The economic impacts of highways can be direct and indirect (Rodrigue, 2006). With respect to direct economic impacts, good highway systems support economic growth by reducing the transport costs. Direct user benefits include reductions in travel time, increased reliability, and increased safety in the movement of people and goods. As highway costs are lowered, resources are freed for other purposes (Dalenberg and Partridge, 1997). Therefore, people can benefit from increased employment options as their range of feasible commuting patterns is expanded.

The reduced transportation cost due to highway improvements may have various impacts on the regional economy (Kelejian and Robinson, 2006; Rietveld, 1989). Figure 1 illustrates the relationship between highway improvement or development and local economic development. Transportation cost reduction provides price advantages to exported goods because of reduced production cost, to intermediate goods due to declined delivery cost, and to imported goods due to decreased importing cost.

FIGURE 1. Effects of Highway Improvement/Development



Source: Kelejian & Robinson, 2006; Kovalyova & Robinson, 2004; Lakshmanan and Anderson, 2004

The cheaper exported goods can have an increase in demand, expansion in market size, and enhancement in local production and employment. The cheaper imported goods have both positive and negative effects on regional economic growth. The positive impacts include increased income due to the lower price of the imported goods. This increased income can lead to increased final demand in the local area, and then increased local production and economic growth. The negative impacts include a decrease in the consumption of more expensive goods produced in the local area, which can make local firms that produce the same goods less competitive, and ultimately decrease local production and employment.

One of the key components in regional development is employment or job growth. If a region can create more jobs and then attract more people, the demand for goods and services can be increased by the population growth. Therefore, job creation in a region attracts more people and more people are thus able to find employment. New highways and highway improvements can improve the accessibility and contribute to regional employment growth and economic development (Stephan, 1997; Islam, 2003).

Another example is that reduction of transportation costs from highway improvements can motivate a firm to move to a particular area so that it can take advantage of scale economies. An important thing in industrial location is the trade-off between scale economies and transportation costs (Anderson and Lakshmanan, 2004).

Section two of this paper explains the research objective. Section three discusses the model and data. Section four describes the results. Finally, Section five summarizes the main conclusion.

II. Research Objective

The goal of this paper is to study how highways of a county and neighboring counties affect employment in that county. Using a spatial econometric method, this paper analyzed spatial patterns in the employment growth process in Missouri. The OLS model was run and spatial effects were examined. A spatial lag model was used in order to correct for spatial dependence. A spatial lag model was adopted through diagnostic tests for the robustness of the results. Finally, maps of employment growth residuals were made to analyze whether the spatial patterns respond to the socioeconomic trends in the region from 1990 to 2000. The model uses employment growth[1] between 1990 and 2000 as the dependent variable.

III. Model and Data

This research was executed for cross-sectional units (114 counties) in Missouri. The empirical models have an OLS model (Equation 1) and a spatial lag model (Equation 3) with a spatially-weighted lag.

$$\begin{aligned} EMPGRT = {} & \alpha_0 + \alpha_1 (EDRT90) + \alpha_2 (LnPOPD90) + \alpha_3 (LnPVRT90) + \alpha_4 \\ & (LnHHIM90) + \alpha_5 (UNEMP90) + \alpha_6 (LnAWPJ90) + \alpha_7 \\ & (4LANED90) + \alpha_8 (2LANED90) + \alpha_9 (W4LANED90) + \alpha_{10} \\ & (W2LANED90) + DVRL + DVIS + \varepsilon_i \cdots\cdots\cdots\cdots \text{(Equation 1)} \end{aligned}$$

Anselin's (1988a) methodology to construct a spatial lag model is adapted in this paper. Anselin (1988a) and Anselin and Bera (1998) define spatial lag models as autoregressive models of the following form:

$$y = \rho Wy + X\beta + u, \qquad u \sim N(0, \sigma^2_v I) \cdots\cdots\cdots\cdots \text{(Equation 2)}$$

where the dependent variables are spatially lagged by being weighted with a predetermined spatial weight matrix: W, of J*J elements; y is a J*1 vector of endogenous measure for the J regions; X is a J*k matrix of exogenous variables; β is a k*1 vector of corresponding coefficients; and u is a J*1 vector of error terms.

For the spatial lag model, there is a distinction between the residual and prediction error. The latter is the difference between the observed value

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[1] Employment growth = (total employment in 2000 - total employment in 1990)/ total employment in 1990.

and the predicted value that uses only exogenous variables, rather than treating the spatial lag Wy as observed. To determine the extent of spatial spillovers, I will use geographic queen contiguity[2] as the weight matrix (W) to assign

TABLE 1. Independent Variables[3]

Variable	Definition	Scale	Expected effect	Data Source
EDRT90	Percentage of people, 25 and older, with high school degree or higher in 1990	County	+	US Census
LnPOPD90	Log of person per square mile of land area in 1990	County	+	US Census
LnPVTY90	Log of number of people below poverty level in 1990	County	-	US Census
LnHHIM90	Log of household income in 1990	County	+	US Census
UNEMP90	Unemployment rate in 1990	County	-	US Census
LnAWPJ90	Log of average wage per job in 1990	County	-	US Census
4LANED90*1)	Mileage density of four-lane roads in 1990	County	+	MO Dept. of Transportation
2LANED90	Mileage density of two-lane roads in 1990	County	+	MO Dept. of Transportation
W4LANED90*2)	Spatially-weighted mileage density of four-lane roads in 1990	County	+	Calculated
W2LANED90	Spatially-weighted mileage density of two-lane roads in 1990	County	+	Calculated
DVRL	Dummy to reflect rural county	County	-	US Census
DVIS	Dummy variable for county with interstate highways	County	+	GIS

*1) Mileage density of road with 4 lanes in 1990 = Miles of road with 4 lanes in 1990 / county land area (square miles).

*2) Spatially-weighted mileage density $([Wx]_i) = ([Wx]_i = \Sigma_j w_{ij} x_{uj}$, where w_{ij} is an (i, j) element of the spatial weights matrix W (spatial queen matrix).

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2 Queen contiguity adds a spatial corner relationship between two neighbors without a common border. An example for queen contiguity would be the two states Arizona and Colorado.

3 These independent variables are related to industrial location factors. Industrial location factors (Smith, 1981) are land, capital, materials, labor, market, transportation infrastructure, agglomeration, public policy, organization, and cost.

structure to the spatial interdependence that is likely present across the counties sharing a same boundary in the region. In this model, when only direct neighbors interact, the local spatial multiplier WX or $(1-\rho W)^{-1}X$ measures the spatial spillovers. ρ is the spatial autoregressive coefficient that reflects the reaction of Y to economic growth in neighboring regions, i.e., spatial spillovers.

$$\begin{aligned} EMPGRT = {} & \alpha_0 + \rho(W\_EMPGRT) + \alpha_1(EDRT90) + \alpha_2(LnPOPD90) + \alpha_3 \\ & (LnPVRT90) + \alpha_4(LnHHIM90) + \alpha_5(UNEMP90) + \alpha_6(LnAWPJ90) \\ & + \alpha_7 (4LANED90) + \alpha_8(2LANED90) + \alpha_9(W4LANED90) + \alpha_{10} \\ & (W2LANED90) + DVRL + DVIS + \varepsilon_i \quad \cdots\cdots\cdots \text{(Equation 3)} \end{aligned}$$

The dependent variable is the total employment growth for the sum of all industries (EMPGRT) between 1990 and 2000. This paper uses employment of the civilian labor force, published by the Economic & Policy Analysis Research Center (EPARC) at the University of Missouri-Columbia. Employment growth is used to reflect economic development because job growth is a common policy objective for regional development.

The demographic and socio-economic data, such as educational achievement, population density, poverty status, household income, unemployment rates, and average wage per job, were obtained from the Missouri Quick Facts from the U.S. Bureau of the Census, Economic Research Service of the USDA, the U.S. Bureau of Economic Analysis, and the U.S. Department of Labor. Mileage densities of roads with two and four lanes came from the Missouri Department of Transportation. Spatially-weighted mileage densities of two- and four-lane roads were calculated from the GeoDa program. Table 1 describes explanations of the explanatory variables.

Mileage density of two- and four-lane roads (4LANED90 and 2LANED90), spatially-weighted mileage density of two- and four-lane roads (W4LANED90 and W2LANED90) and the dummy variable for counties with interstate highways (DVIS) are used to explain highway investment impacts on employment indirectly. Those W4LANED90 and W2LANED90 variables were calculated using the GeoDa program in order to investigate how two- and four-lane roads of neighboring counties that share the same boundary affect the employment within a county, using a queen spatial contiguity weight matrix.

The education achievement (EDRT90) is measured in terms of the percentage of people, 25 years of age and older, who have high school degrees or higher in 1990 to investigate labor force qualification. The population density (LnPOPD90) is the measure of labor market size. Poverty level (LnPVTY90) considers the possibility of low-skilled workers, implying that it may have a negative effect on attracting firms to a local area. Household income (LnHHIM90) shows the consumption power of the region. Wage (LnAWPJ90) is the average wage per job, which reflects local cost factors.

IV. Results

The preliminary results of OLS (Table 2) do not correspond with the expected outcomes, according to transportation factors like 4LANED90, 2LANED90, and DVIS.

As for the other independent variables, population density (LnPOPD90) and household income (LnHHIM90) have statistically significant coefficients with the expected signs.

TABLE 2. OLS Regression Results

Variable	Coefficient	Std.Error	t-Statistic	Probability
CONSTANT	0.7221	1.6254	0.4442	0.6578
EDRT90	0.0244	0.1832	0.1332	0.8942
LnPOPD90	0.2670	0.1405	1.9007	0.0601
LnPVTY90	-0.0493	0.1159	-0.4252	0.6715
LnHHIM90	0.8273	0.3023	2.7360	0.0073
UNEMP90	0.0070	0.0083	0.8445	0.4003
LnAWPJ90	-1.0194	0.3367	-3.0274	0.0031
4LANED90	-1.0468	0.4153	-2.5205	0.0132
2LANED90	-0.4917	0.3330	-1.4766	0.1428
W4LANED90	-0.3108	0.4549	-0.6832	0.4959
W2LANED90	0.2619	0.5270	0.4971	0.6201
DVRL	-0.0467	0.0489	-0.9562	0.3411
DVIS	-0.0755	0.0355	-2.1235	0.0361

Among the variables that are significant, population density and household income have positive signs, implying that an increase would lead to an increase in employment.

Anselin and Rey (1991) tried to figure out how the Moran I and Lagrange multiplier tests are used by different situations, different sample sizes, alternative spatial structure, and under the non-standard error distributions. Their results are highly sensitive to the properties of the tests by using what kinds of spatial weights matrix. They suggest that the Lagrange multiplier tests are the most powerful in deciphering between a spatial error model and a spatial lag model.

Kelejian and Robinson (1992) tested a large sample for spatial autocorrelation in terms of error terms of regression models. Their results indicate that omitted independent variables may bring spatial autocorrelation in the error terms. Nass and Garfinkle (1992) introduced the localized autocorrelation diagnostic statistic (LADS), which is an error diagnostic. They suggest that the LADS is a good method to diagnose localized residuals and to identify omitted variables in models.

For this paper, Anselin's methods were used to analyze and quantify spatial effects. GeoDa has two tests for diagnostics of spatial dependence: Moran's I and the Lagrange Multiplier test.

The Moran's I statistic is used (Moran, 1948; Cliff and Ord, 1981) to estimate and test hypotheses. Moran's I measures spatial autocorrelation in regression residuals.

TABLE 3. Diagnostics for Spatial Dependence

Test	MI/DF	z-value	Probability
Moran's I (error)	0.173096	3.6610536	0.0002512
Lagrange Multiplier (lag)	1	10.4792339	0.0006752
Robust LM (lag)	1	3.5441000	0.0597576
Lagrange Multiplier (error)	1	8.2130226	0.0041591
Robust LM (error)	1	0.2006887	0.6541655

$$I = \frac{n}{\sum_i \sum_j w_{ij}} \cdot \frac{\sum_i \sum_j w_{ij}(y_i - \mu)(y_j - \mu)}{\sum_i (y_i - \mu)^2} \quad \text{(Equation 4)}$$

where w_{ij} is equal to the elements of the spatial weight matrix, W; is the mean of all y observations; and i, j = 1,⋯, n. A positive and significant value of Moran's I indicates a positive spatial correlation, showing that counties have levels of employment (high or low) similar to their neighboring counties. A negative and significant value for Moran's I indicates negative spatial correlation, showing that counties have levels of employment unlike neighboring counties, and a low value may be surrounded by high values in nearby counties.

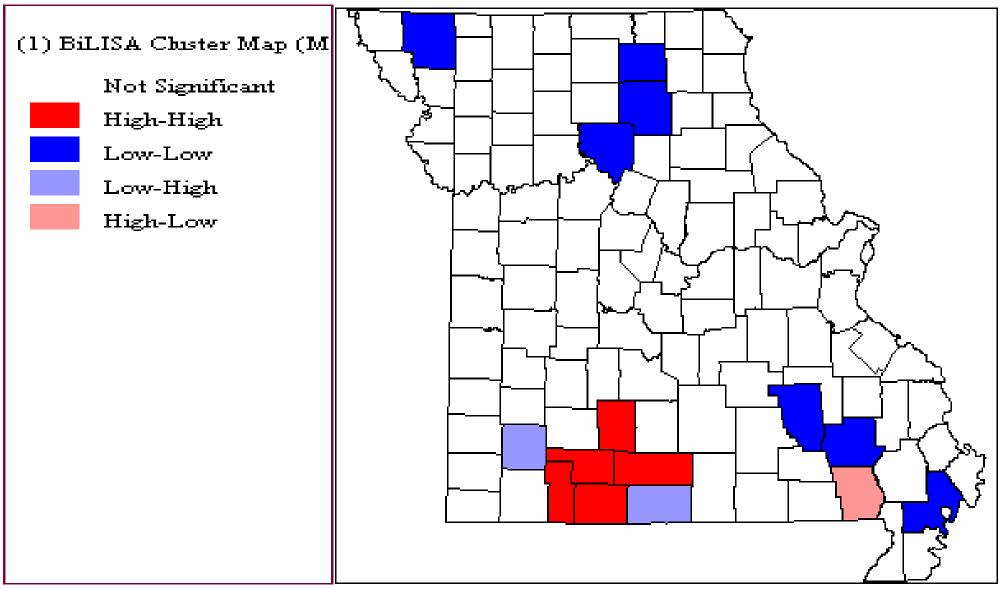
Moran's I test on the OLS yields a significant and positive result of 0.1731 ($z = 3.6611$ and $p < 0.00025$). These show a significant and positive spatial relationship (Anselin, 1988 and 1995). The diagnostics for spatial dependence in OLS suggest a spatial lag correlation.

Lagrange Multiplier (LM) was used for choosing spatial lag or error model. Lagrange Multiplier tests on the OLS show that LM (lag) and robust LM (lag) are both significant and positive values of 10.4792 ($p < 0.0068$) and 3.5441 ($p < 0.05976$), respectively. LM (error) is significant and positive at 8.2130 ($p < 0.00416$) and robust LM (error) is insignificant. The test indicates that the spatial lag model is better than the spatial error model for spatial econometric model because LM-lag tests have higher significant values than LM-error tests.

The local Moran's I test was suggested by Anselin (1995). The local Moran's I investigates whether the values for each county (from the global Moran's I) are significant and how influential they are individually for the overall spatial autocorrelation. Figure 2 displays an interesting pattern with significant clusters of counties with large rates of employment growth (High-High) in the south-central area of Missouri. Areas with a low rate of employment growth (Low-Low) are apparent in the western and central north, as well as in the south east.

The residuals of employment growth were mapped from the OLS model in order to determine if there was a spatial pattern. Residuals can be obtained by subtracting the predicted values from the actual values. A residual

FIGURE 2. Moran Significance Map



map gives an indication of systematic over-prediction or under-prediction in counties, indicating there is spatial autocorrelation. The OLS residuals make a standard deviational map for the residuals.

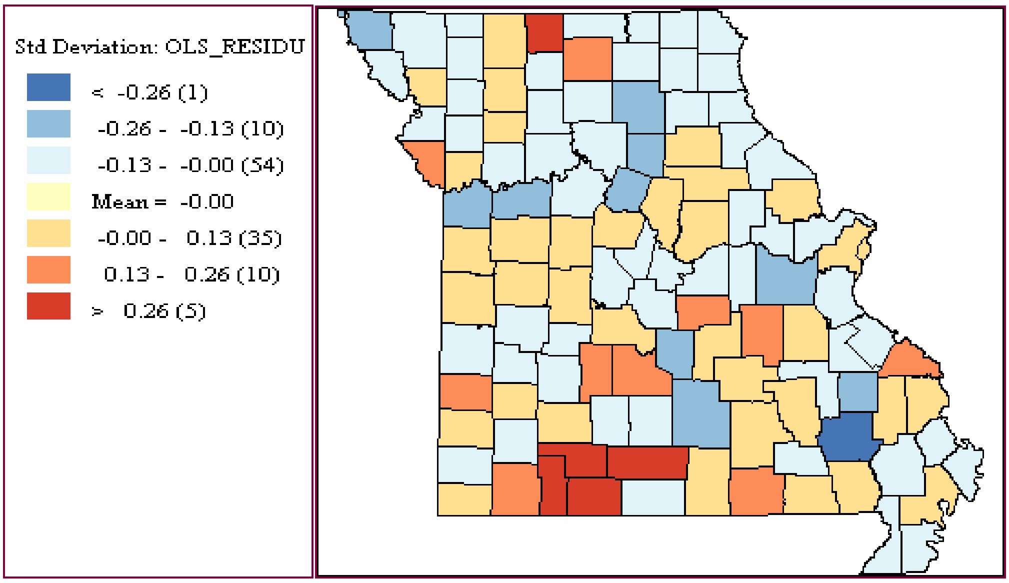
Figure 3 suggests that similarly-colored areas tend to be clustered throughout Missouri, indicating positive spatial autocorrelation (Anselin, 2005). Also, it indicates a tendency to over-predict (negative residuals) in most northern areas and in scattered central and southern areas, as well as a tendency to under-predict (positive residuals) in the central and southern areas. This implies the possible presence of spatial heterogeneity (Anselin, 2005). A negative standard deviation means that the predicted values exceeded the actual values.

Figure 3 shows a similar portion of over-predictions and under-predictions of employment growth in the OLS model. Similarly, there is some clustering.

Spatial dependence exists when the dependent variable or error term at each location is correlated with the dependent variable or the error term at other locations (Anselin 2001, Islam 2003).

The spatial lag model reflects misspecifications similar to omitting a significant explanatory variable in the regression model. In this case, however,

FIGURE 3. Mapping the OLS Residuals of Employment Growth



the OLS is biased and all inferences based on the standard regression model will be inconsistent.

The spatial lag model attempts to explain spatial dependence in stock-like variables for a cross-section of spatial units at one point in time. The spatial lag model directly specifies the concept of "neighborhood" for each region with the introduction of the spatial weight matrix, W. The elements of the weight matrix reflect the relative importance of spatial dependence between regions. Assuming that the spatial dependence between regions decreases with the distance between them, a distance weight matrix can be used for the spatial lag model. Explanatory variables for spatial lag models include exogenous variables similar to the propulsive and attractive factors used in spatial interaction models.

The spatial autoregressive coefficient (ρ) of the spatially-weighted lag employment growth (W_EMPGRT) is estimated as 0.374 and is significant ($p < 0.0004$). This positive spatial autoregressive coefficient indicates that a higher level of employment in a county significantly increases the employment in the neighboring counties. Therefore, there exists a positive spatial interaction between the county employments of surrounding regions.

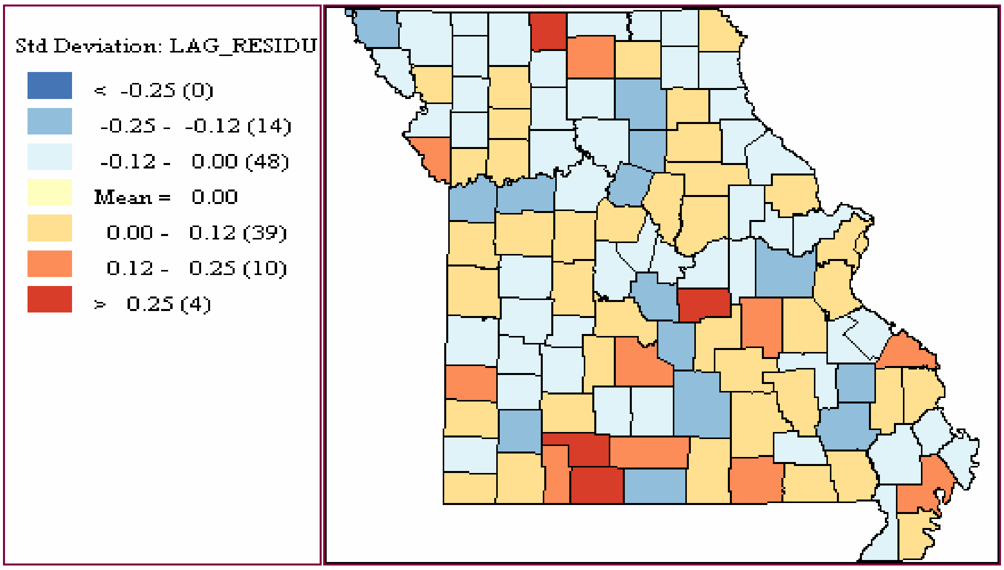
As LANES2, LANES4 and DVIS served as proxies for highway improvement in a county, the variable of “mileage of road with four lanes” (4LANED90) has a significant and negative effect, but “two lanes” shows an insignificant and negative sign. This indicates that “two lanes” and “four lanes” are not effective factors in attracting employment. The “dummy” variable (DVIS) for counties with interstate highways is significant and negative. It shows that interstate highways in a county have negative effects on employment, implying that interstate highways are also not a key complement to attract employment.

With respect to the spatially-lagged variables of “mileage of road with four lanes” (W4LANED90) and “two lanes” (W2LANED90), those coefficients are limited to the spatial effects via four- and two-lane roads on employment spillovers. While the “four-lane road mileage in its neighboring counties” has an insignificant and negative effect on employment in the county, the “two-lane roads in its surrounding counties” has an insignificant and positive impact on employment in the county.

TABLE 4. Spatial Lag Model - Maximum Likelihood Estimation

Variable	Coefficient	Std.Error	t-Statistic	Probability
CONSTANT	0.3570	1.4464	0.2468	0.8050
W_EMPGRT	0.3743	0.1068	3.5043	0.0004
EDRT90	0.0087	0.1623	0.0535	0.9572
LnPOPD90	0.2286	0.1245	1.8349	0.0665
LnPVTY90	-0.0581	0.1027	-0.5656	0.5716
LnHHIM90	0.6740	0.2756	2.4452	0.0144
UNEMP90	0.0046	0.0074	0.6285	0.5296
LnAWPJ90	-0.7664	0.2996	-2.5577	0.0105
4LANED90	-0.9906	0.3679	-2.6924	0.0070
2LANED90	-0.4275	0.2950	-1.4491	0.1472
W4LANED90	-0.1852	0.4049	-0.4576	0.6472
W2LANED90	0.2230	0.4672	0.4775	0.6330
DVRL	-0.0438	0.0433	-1.0132	0.3109
DVIS	-0.0647	0.0316	-2.0471	0.0406

FIGURE 4. Mapping the Residuals of Employment Growth from the Spatial Lag Model



Population density (LnPOPD90) and household income (LnHHIM90) have both significant and positive signs, indicating that greater market size and higher consumption power attract more jobs to local areas. “Average wage per job”(LnAWPJ90) is significant and negative, suggesting that higher local costs lead to a decrease in employment.

Considering the order of the Wald (W), Likelihood Ratio (LR), and Lagrange Multiplier (LM) statistics on the spatial autoregressive error co-efficient as a way to compare the MLE results to the OLS results, it was found that W = 12.280 (the square of the z-value of the asymptotic t-test, 3.504312), LR = 11.5564, and LM = 10.4792. This corresponds to the ex-pected order (W > LR > LM) (Anselin, 1988 and 2005) and therefore in-dicates that this Maximum Likelihood Estimation (MLE) is better than the OLS.

The maps of the spatial lag model residuals (Figure 4) shows that the spatial patterns of employment growth are slightly different than the OLS model. Across Missouri, the portion of under-predicted and over-predicted areas in employment growth is similar to the OLS model.

V. Summary and Conclusion

Though this research analyzes only the state of Missouri, the results may have expanded adaptation. Economic development advocates and public officials often advance the notion that more highways will automatically lead to more development. The results of this research may help in developing consistent regional policies that ensure greater efficiency of highway capital and better evaluate user benefits. It appears that highways do not contribute to regional growth and development. However, the relationship between highway investment and economic development is multifaceted and highly complex.

This paper has investigated the extent to which employment growth in a county is affected by highway investment spillovers from neighboring counties as well as in the county itself. In this analysis, interstate highways in Missouri have negative effects on employment growth. Both “two lane highways” and “four lane highways” in a county have a negative sign. It may indicate that the investment of two- and four-lane roads may induce a decrease in employment growth among counties, contrary to expectations. Those of surrounding counties are insignificant and negative in “four-lane highways” and positive in “two-lane highways.” It shows that there are no significant geographic highway investment externalities across boundaries.

Therefore, it can be generalized that too-dense road networks can be detrimental to local areas, and that highway over-investment can lead to diminishing employment returns. The positive spatial autoregressive coefficient (ρ) implies positive spatial dependence between counties, indicating that employment in neighboring counties affects a county’s employment positively.

It is expected that this research helps identify and quantify potential spatial relationships between highway investments and economic growth. This study implies that road lane improvement may be a good tool to develop regional economy, but that additional new highway miles may be harmful to the employment growth, indicating that the results do not support additional lane miles. Therefore, state-level transportation officials may reconsider funding and construction plans of new highways that justify the expenditures as a means to aid economic growth.

The general hypothesis that a mature transportation network does not provide a region with additional benefits from an increase of lane-miles and new highway construction is supported by this research. Still, this paper has explored a limited number of econometric and spatial econometric specifications, and further investigation may prove profitable.

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