Road infrastructure, spatial spillover and county economic growth

Zhenhua Hu, Shuang Luo
Business School, Central South University, Changsha 410083, China

Abstract. This paper analyzes the spatial spillover effect of road infrastructure on the economic growth of poverty-stricken counties, based on the spatial Durbin model, by using the panel data of 37 poor counties in Hunan province from 2006 to 2015. The results showed that there is a significant spatial dependence of economic growth in Poor Counties. Road infrastructure has a positive impact on economic growth, and the results will be overestimated without considering spatial factors. Considering the spatial factors, the road infrastructure will promote the economic growth of the surrounding areas through the spillover effect, but the spillover effect is restricted by the distance factor. Capital investment is the biggest factor of economic growth in poor counties, followed by urbanization, labor force and regional openness.

1 Introduction
An empirical study of the impact of infrastructure on regional economic growth dates back to Aschauer[1], which uses US time series data to study the relationship between US productivity and infrastructure investment, and the results show that the core infrastructure such as expressways increased investment and contributed significantly to productivity gains in the United States. Since then, more and more domestic and foreign scholars began to pay attention to the impact of infrastructure on economic growth. Early empirical research focused on whether infrastructure construction had a significant impact on regional economic growth. Some foreign scholars[2,3] use time series data to get the flexibility of infrastructure output significantly different from zero. But Tatom[4] makes a regression analysis for Aschauer’s data, using the first order differential, it is found that the flexibility of the infrastructure is not significantly different from zero. With the deepening of research, domestic and foreign scholars began to use the panel data and introduce spatial geography factors into the analysis of the impact of infrastructure on economic growth, the research focus has gradually shifted to the spatial spillover of infrastructure. Holtz-Eakin and Schwartz[5] first introduced the spatial weight matrix into the panel data model and found that the output elasticity of the adjacent regional infrastructure was not significantly different from zero. Later, the study of Cohen[6] and Liu Yuhong[7] concluded that the surrounding area transport infrastructure has a significant positive effect on local economic growth, especially Yuhong Liu studied the spatial spillover effect by introducing an OTR, which represents the adjacent transportation infrastructure variable in the panel data model. Moreover, Some studies[8,9] have shown that there is a negative spillover effect, in which Zhang Xueliang[10] found that transportation infrastructure has a negative spillover effect on economic growth in the population density weight matrix. Based on the previous studies, this paper attempts to construct the spatial Durbin model under the three weight matrices, study the direct effect of the road infrastructure and the spatial spillover effect on the surrounding counties.

2 Model Setting
Spatial weight matrix is the basis of spatial panel data model analysis, which reflects the positional
relationship between spatial units. At present, there is no uniform standard to regulate the setting of the spatial weight matrix, and the researchers usually determine the spatial weight matrix according to research needs. In this paper, three different forms of spatial weight matrices are constructed: binary adjacency weight matrix (W1), economic distance weight matrix (W2), nested weight matrix (W3).

According to the spatial correlation source, the spatial panel data model has three basic forms: spatial lag model, spatial error model, spatial Durbin model. The spatial Durbin model (SDM) takes the form:

\[ Y = \delta WY + X \beta + WX \theta + \mu + \lambda + \varepsilon \]  

(1)

\( Y \) is the explained variable, \( WY, WX \) are spatially lagged explained and explaining variables, \( W \) is spatial weight matrix, \( X \) is explaining variables, \( \mu \) is spatial effect, \( \lambda \) is time-period effect, \( \varepsilon \) is random error term, \( \delta \) is spatial autoregressive coefficient, \( \beta, \theta \) are coefficient column vector. Moreover, SDM can also test two original hypothesis:

\[ H_0 : \theta = 0 \quad \text{and} \quad H_1 : \theta + \delta \beta = 0 \]  

(2)

Based on the above model theory, it is assumed that the county economic growth conforms to the Cobb Douglas production function, introducing the core variable road infrastructure and the control variables urbanization, regional openness, builds the basic model:

\[ Y_{it} = L_{it}^{\alpha} K^{\beta}_{it} Urban_{it}^{\kappa} Iop_{it}^{\rho} Road_{it}^{\lambda} \]  

(3)

\( Y_{it}, L_{it}, K_{it}, Urban_{it}, Iop_{it}, Road_{it} \), respectively, the total output of county, labor, capital investment, urbanization, regional openness, road infrastructure.

Since we focus on the spatial spillover effect of road infrastructure, combining with SDM, take the natural logarithm on both sides of (3) equation at the same time, the final model form is set in the empirical analysis part:

\[ \ln y_{it} = \delta \sum_{j=1}^{N} w_{ij} \ln y_{jt} + X_{it} \beta + \sum_{j=1}^{N} w_{ij} X_{jt} \theta + \mu_i + \lambda_t + \varepsilon_{it} \]  

(4)

3 Variable description and data source

This paper study the impact of road infrastructure on county economic growth in 37 poor counties in Wuling mountainous area of Hunan Province from 2006 to 2015 panel data. Most data comes from Hunan Statistical Yearbook and the statistical yearbook of prefecture-level cities and autonomous counties of poor counties. A small amount of data comes from the Statistical Bulletin of the Hunan Provincial Statistical Information Network. The few missing data are filled with linear interpolation.

Economic Growth Indicator (Y). Select the real GDP as an alternative to economic growth indicator, the real GDP approach: the real GDP = 2006 GDP × 2006 as the base year of the GDP index.

Road Infrastructure Indicator(Road). This paper uses road mileage as a substitute variable for road infrastructure indicator.

Labor Force Indicator(Labor). Use the number of employees at the year-end to measure labor force.

Capital Indicator (Invest). Use the real investment in fixed assets to measure the real capital investment, consistent with the way of GDP, calculate the real investment according to the constant price of 2006.

Urbanization Indicator(Urban). The proportion of urban population to total population indicates the level of urbanization.

Regional Openness Indicator (Iop). Use the proportion of real import and export total to real GDP as a regional open alternative variable. Real import and export approach: nominal total is converted into RMB by the exchange rate at the current, then converted into actual total in the year of 2006 by the consumer price index.

4 Empirical analysis

4.1 Spatial correlation test

The spatial autocorrelation test of county real GDP is carried out using Moran’s I index. It can be seen
from Table 1 that the Moran's I values are significant positive under the three spatial weight matrices, indicating that there is significant positive spatial correlation between county economic growth. From the perspective of weight matrix, the Moran’s I index under the nested weight matrix is smaller than the Moran’s I index in the adjacency matrix and the economic matrix, indicating that the adjacency matrix and the economic matrix amplify the positive spatial correlation between the counties. The Moran’s I index has a slight fluctuation under the three weight matrices, but the whole is more stable.

| Year | W1     | W2     | W3     |
|------|--------|--------|--------|
|      | I-value| P-value| I-value| P-value| I-value| P-value|
| 2006 | 0.304  | 0.001  | 0.487  | 0.000  | 0.214  | 0.002  |
| 2007 | 0.306  | 0.001  | 0.482  | 0.000  | 0.217  | 0.001  |
| 2008 | 0.295  | 0.002  | 0.475  | 0.000  | 0.214  | 0.002  |
| 2009 | 0.292  | 0.002  | 0.481  | 0.000  | 0.214  | 0.002  |
| 2010 | 0.292  | 0.002  | 0.481  | 0.000  | 0.219  | 0.001  |
| 2011 | 0.303  | 0.001  | 0.485  | 0.000  | 0.224  | 0.001  |
| 2012 | 0.309  | 0.001  | 0.486  | 0.000  | 0.228  | 0.001  |
| 2013 | 0.318  | 0.001  | 0.492  | 0.000  | 0.228  | 0.001  |
| 2014 | 0.333  | 0.001  | 0.500  | 0.000  | 0.236  | 0.001  |
| 2015 | 0.342  | 0.000  | 0.501  | 0.000  | 0.249  | 0.000  |

4.2 Empirical model estimation results and analysis
Before using spatial panel data model estimation, it is usually necessary to perform Hausman test, LR test and LM test. Because the LM statistic needs to get the residual of the mixed panel data model under OLS, the model without spatial effect is needed as the reference, the OLS estimation of panel data model is carried out first.

4.2.1 Estimation of results and analysis of panel data model without spatial effect. It can be seen from Table 2 that the Hausman test results reject the original hypothesis that the random effect is significant at 1% significant level under the three weight matrices, so the fixed effect model is selected. According to the results of two LR test, it is suggested that the spatial and time-period fixed effects model should be selected. In addition, the results of LM test under each weight matrix show that most of the significance level of LM test are more than 5%, which indicates that there is spatial correlation between panel data. The results of LM test under W2 weight matrix show that spatial correlation comes from spatial error, the SEM should be selected for estimation. Under W3 weight matrix show that spatial correlation comes from spatial lag, the SLM should be selected for estimation.

Table 2:OLS estimation of panel data model with spatial and time-period fixed effects, Model test results

| Variable | Coefficient | Std. Error | t-stat | P-value |
|----------|-------------|------------|--------|---------|
| Labor    | 0.068***    | (2.754)    |        |         |
| Invest   | 0.492***    | (17.344)   |        |         |
| Urban    | 0.209***    | (3.888)    |        |         |
| Iop      | 0.008***    | (3.353)    |        |         |
| Road     | 0.083***    | (4.396)    |        |         |
| LR joint significance | 310.552*** |            |        |         |
To further determine the model form, we conducted Wald test and LR test under three weights. Their original hypothesis are (2) equation. It can be seen from Table 3, the original hypothesis that SDM can be simplified to SLM or SEM under each weight matrix are rejected at a significance level of 1%. Elhorst has pointed out that if the Wald, LR test conflicts with the LM test, setting the spatial panel data model, a more generalized SDM should be selected to ensure the confidence of the estimated results. Therefore, this paper uses the spatial Durbin model under spatial and time-period fixed effects.

4.2.2 Spatial Durbin model estimation results. Considering the spatial effect, it is necessary to carry out the maximum likelihood estimation for parameters of spatial Durbin model under three weight matrices by Matlab software. The results are shown in Table 4.

|                      | W1      | W2      | W3      |
|----------------------|---------|---------|---------|
| Ln Labor             | 0.030   | 0.085***| 0.065***|
|                      | (1.248) | (3.372) | (2.616) |
| Ln Invest            | 0.475***| 0.527***| 0.430***|
|                      | (17.001)| (18.103)| (14.606)|
| Ln Urban             | 0.211***| 0.221***| 0.155***|
|                      | (4.005) | (4.015) | (2.786) |
| Ln Iop               | 0.006***| 0.007***| 0.005** |
|                      | (2.737) | (3.173) | (2.260) |
| Ln Road              | 0.052***| 0.054***| 0.041***|
|                      | (4.426) | (4.556) | (3.378) |
| W*Ln labor           | -0.081  | 0.035***| 0.041***|
|                      | (-1.395)| (4.136) | (2.999) |
| W*Ln invest          | 0.333***| 0.214***| 0.299***|
|                      | (4.674) | (2.692) | (3.465) |
It can be seen from Table 4 that the significance level of spatial autoregressive coefficient $\delta$ are significantly positive and more than 10% under the three weight matrices, indicating that there is significant spatial dependency between real GDP in adjacent counties. In addition, the results of $|\delta|<1$ show that the robustness of model estimation is ensured under each weight matrix.

4.2.3 The analysis of direct effect and indirect effect. In the spatial Durbin model, the coefficient point estimate in Table 4 does not account for the direct effect of the explaining variables due to the existence of feedback effects. Therefore, it is necessary to use the partial differential method to accurately measure the direct effect and indirect effect of the explaining variables. The effect decomposition of explaining variables is shown in Table 5.

| Effects            | Explaining variables | W1     | W2     | W3     |
|--------------------|----------------------|--------|--------|--------|
| Direct effect      | Ln Labor             | 0.029  | 0.074*** | 0.072*** |
|                    | Ln Invest            | 0.485*** | 0.523*** | 0.438*** |
|                    | Ln Urban             | 0.213*** | 0.212*** | 0.162*** |
|                    | Ln Iop               | 0.006*** | 0.007*** | 0.005*** |
|                    | Ln Road              | 0.055*** | 0.052*** | 0.042*** |
|                    | Ln Labor             | -0.086 | 0.029*** | 0.048*** |
| Indirect effect    | Ln Invest            | 0.439*** | 0.091   | 0.428*** |
|                    | Ln Urban             | 0.117  | 0.250   | 0.269   |
|                    | Ln Iop               | -0.010* | 0.009   | -0.004  |
|                    | Ln Road              | 0.119*** | 0.063*  | 0.073**  |

Direct effect analysis. According to Table 5, the direct effect of road infrastructure under the three weight matrices is less than the coefficient of 0.083 corresponding to the non-spatial model, which indicates that the non-spatial model overestimates the direct effect of road infrastructure on local economic growth. The direct effects of road infrastructure under the three weight matrices are 0.055, 0.052 and 0.042 respectively, and the 1% significance test shows that road infrastructure has a positive effect on the local economic growth. Poor counties rely mainly on road transport, and the improvement of road infrastructure makes production materials and labor in the local mountainous
areas better able to gather in cities and towns to promote local economic growth.

Indirect effect analysis. The indirect effect of road infrastructure is significant under the three weight matrices. Spatial spillover effect is 0.119 under the adjacency weight matrix, it was respectively reduced by 0.063 and 0.073 under the economic weight matrix and nested weight matrix, considering the distance factor. It indicates that the road infrastructure promote the economic growth of the surrounding counties by the distance factor constraints. Compared with the direct effect and indirect effect of the road infrastructure under three weight matrices, it is found that the indirect effect is greater than the direct effect under the corresponding weight matrix, which shows that road infrastructure promote economic growth in all counties more through the spillover effect due to the network. The network road infrastructure reduces the transportation cost between the counties, promotes the flow of manpower, information, capital and technology between the counties, strengthens economic ties and cooperation between the counties, thus drives the economic growth around the county.

5 Conclusions
This paper makes use of panel data of 37 poor counties in Wuling Mountain, Hunan Province from 2006 to 2015, analyzes the spatial spillover effect of road infrastructure on economic growth of poverty-stricken areas by constructing the spatial Durbin model under three spatial weight matrices. The main conclusions are as follows: First, there is significant spatial dependency between county economic growth, that is, the spatial agglomeration in the poor counties with similar economic development level in the Wuling Mountain area. Second, the road infrastructure has a significant impact on promoting local economic growth. Without considering the spatial factors, the direct effect of the road infrastructure will be overestimated. Thirdly, the road infrastructure has a significant positive direct and indirect effect on economic growth, and the indirect effect is greater than the direct effect, indicating that the road infrastructure can not only promote the local economic growth, but also through the inter-county road transport network, inline, interconnected, greater extent to promote the economic growth around county. Fourthly, it is concluded that the direct effect of capital investment is the largest, followed by urbanization, labor force and regional openness.

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