Spatial Impact of Transportation Infrastructure: A Spatial Econometric CGE Approach

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Abstract

Transportation infrastructure plays an important role in regional economic development both in the stimulation of growth and as a response to output expansion. However, measuring these effects quantitatively has been a challenge due to the complicated impact mechanisms of transportation infrastructure. This complication is due to two reasons: first, regional impacts of transportation infrastructure are achieved through a mechanism that involves both a demand influence through the variation of transportation price and a supply influence implemented through the variation of transportation cost; second, impacts of transportation are usually evaluated in a regional context where the presence of unobserved local or regional variables may give rise to spatial autocorrelation. As a result, impact analysis may become biased and spurious. This study develops a new method called Spatial Econometric Computable General Equilibrium (SECGE) model, which integrates both spatial econometrics with equilibrium modeling to improve the effectiveness of impact analysis on transportation infrastructure.

This study differs from previous studies in the following three aspects: First, through a spatial autocorrelation test, the presence of spatial dependence is observed and confirmed among the elasticities of factor substitution in the US. To deal with spatial dependence, spatial panel econometric techniques are introduced to estimate the elasticity of factor substitution of different sectors for the Constant Elasticity of Substitution (CES) production function with consideration of spatial direct and indirect effects.

Second, transportation impact analysis is conducted under different scenarios of general equilibrium frameworks. Unlike partial equilibrium analysis, general equilibrium analysis allows researchers to obtain a more comprehensive understanding of transportation infrastructure's impacts given its consideration of interactions between the demand and the supply. The study validates the method by comparing traditional equilibrium simulation without controlling for spatial dependence and the new equilibrium simulation with consideration of spatial dependence.

The comparison allows researchers to appreciate the spatial impacts of transportation infrastructure.

Third, the study is conducted with a focus on multimodal transportation systems that includes: road, rail, air, public transit, pipeline and water. Unlike a unimodal perspective, this multimodal perspective is essential to achieve a comprehensive understanding of the investment impacts in the transportation infrastructure system as a whole. It also enables us to compare impacts and their spillovers between different types of infrastructures and understand the relative importance of transportation investment by mode.

1. Research Questions

Three research questions will be answered in this study: how does public transportation infrastructure contribute to economic outputs in the US? How do such impacts vary among different modes of transportation? And does the impact differ when comparing the estimation with and without consideration of spatial dependence in CGE?

2. CGE Structure

The modeling structure of the study adopts an edited version of a single country CGE model in the tradition of the *IFPRI* standard model, or the Dervis-DeMelo-Robinson tradition developed by McDonald (2005). The model is an open economy including 13 commodities, 13 activities, 9 factors, 1 household and 1 rest of world account (ROW). Trade is modeled under the Armington assumption and the assumption of imperfect substitution between domestically produced and imported goods, represented by a one level CES function. In addition, exports are assumed to be imperfect substitutes for domestically produced goods and this is represented by a one level CET function. The small country assumption is relaxed with the export demand function. The model allows for non-traded, non-produced and non-consumed domestic goods.

3. Estimation Procedure

The estimation procedure of the study is carried out sequentially in the following four steps.

The first step is to diagnose spatial autocorrelation.

The second step is to obtain the basic values of elasticity of factor substitution for CGE analysis. The study follows the classical CES production function to estimate the elasticity of factor substitution. The basic equation can be written as:

$$Q = \left[\alpha_{kl} K^{\frac{\sigma_{kl}-1}{\sigma_{kl}}} + (1-\alpha_{kl}) L^{\frac{\sigma_{kl}-1}{\sigma_{kl}}}\right]^{\frac{\sigma_{kl}}{\sigma_{kl}-1}} \quad (1)$$

$$\ln\left(\frac{K}{L}\right) = \sigma_{kl}\ln\left(\frac{1-\alpha_{kl}}{\alpha_{kl}}\right) + \sigma_{kl}\ln\left(\frac{w}{r}\right) \quad (2)$$

Where Q is the composite goods of capital and labor, *w* and *r* represent wage and rental rates, respectively.σ_{kl} and α_{kl} are the substitution elasticity and distribution parameter of K and L. The equation can also be simplified as a linear regression equation:

$$lny = \beta_0 + \beta_1 lnx + \varepsilon \quad (3)$$

where y is the capital-labor ratio, x is the wage-rental ratio, and ε is the independent and identically distributed (iid) error. The elasticity of substitution between capital and labor is represented by β_1. A panel data includes the 48 states and the District of Columbia for 15 years from 1997 to 2011 are collected from Bureau of Economic Analysis (BEA).

The third step is to estimate the elasticity of factor substitution for different sectors using spatial econometric estimation to control for spatial dependence. Given the potential complexity of this issue, a generalized spatial model named "Spatial Durbin Model" (SDM) is adopted as the initial model for the assessment. The general form of substitution elasticity under SDM is written as:

$$\left(\frac{K}{L}\right)_{i,t} = \rho W \left(\frac{K}{L}\right)_{i,t} + \beta \left(\frac{w}{r}\right)_{i,t} + \theta W \left(\frac{w}{r}\right)_{i,t} + \varepsilon_{i,t} \quad (4)$$

$$\varepsilon_{i,t} \sim N(0, \sigma_{i,t}^2 I_n)$$

where $\frac{K}{L}$ and $\frac{w}{r}$ denote capital-labor ratio variable and wage-rental ratio variable, respectively. $W\left(\frac{K}{L}\right)_{i,t}$ and $W\left(\frac{w}{r}\right)_{i,t}$ denote the spatial lag terms of capital-labor ratio variable and wage-rental ratio variable, respectively. i and t represent different regions and time periods. ρ, β and θ denote coefficients that needs estimation. The analysis is conducted based on the same panel data as used in step 2.

During the step 4, a CGE model with an integration of spatial econometric estimates is established. The elasticity of factor substitution which estimated under both non-spatial and spatial econometric models in step 2 and 3 are utilized respectively for CES production function in the CGE. The spatial econometric CGE (SECGE) is the second type of integration. Given the fact that the elasticity of factor substitution is not assumed or calibrated in this equilibrium model, the estimates based on historical data under the spatial econometric approach is expected to be more realistic for policy simulation. In addition, compared to the non-spatial econometric estimation, the spillover effects of factor substitution elasticity can be adequately estimated under the spatial econometric estimation.

4. Findings

Findings of the study have three implications: First, the economic impacts of public transportation infrastructure in the US are confirmed to be positive under the general equilibrium framework. However, the magnitude of impact is much smaller than that have been found in many previous studies.

Second, the study confirms that the US highway and streets plays a dominant role among all transportation infrastructure systems in economic development while public transit and passenger transportation only plays the least important role among the systems.

Third, the study develops a SECGE model for transportation impact analysis. The method integrates spatial econometric estimation with general equilibrium analysis, which enables researchers to control for the issue of spatial dependence under equilibrium. This integration is important as spatial dependence has been observed among some economic sectors through spatial autocorrelation test.