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The broader effects of transportation infrastructure: Spatial econometrics and productivity approaches

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ABSTRACT

The importance of "broader" economic effects of transportation infrastructure has recently become apparent. "Broader" refers to impacts beyond the geographic boundaries within which the infrastructure investments are undertaken. Approaches to estimate "broader" impacts in production and cost function models are evaluated. A contribution of this paper is the empirical demonstration with a cross-section of US states' manufacturing data that ignoring broader effects of a spatially lagged dependent variable can lead to mis-statements of the overall productive impacts of public infrastructure. These inaccuracies can arise because of missing indirect effects and from specification bias that may directly impact the infrastructure elasticity.

1. Introduction

Many studies since the 1980s have attempted to quantify the effects of public infrastructure on various aspects of the economy. Two of the most well-known approaches have included assessments of infrastructure's impacts on productivity, and on production costs. Depending on the context and the methods employed, there are a wide range of findings in these studies, including large positive, close to zero, as well as negative effects. In recent years, research on the impacts of public infrastructure capital has started to incorporate assessments of the spillover benefits and costs across geographic boundaries. This revolution in the field has come at approximately the same time as growth in the area of spatial econometrics, which has facilitated the development of this strand in the infrastructure literature. In light of the recent economic stimulus package in the US that provides funding for transportation infrastructure projects, the time is ripe for a synthesis of the literature on spatial econometrics and public infrastructure, to aid in understanding where and what types of infrastructure could generate the greatest benefits from additional investment. It could also help with prioritization of projects among those being considered for funding.

The first step in this direction is to recognize a need for incorporating measures of "broader" benefits of transport infrastructure in studies of the impacts of public infrastructure capital. In the context of this paper, "broader" benefits refer to the benefits beyond the geographic region, state, or county in which the investment is undertaken. It also refers to the related "indirect" benefits that may result from spatial interactions. This paper describes several techniques used in the literature for measuring the "broader" (or external) benefits (both positive and negative) and how these measurement techniques differ from those for "local" benefits, for a variety of types of transportation infrastructure in general. These techniques include spatial spillovers (or lags), spatial multipliers, and spatial autocorrelation, all of which can be addressed through the empirical tools of spatial econometrics. Finally, an original data analysis is presented of a cross-sectional production function model for the US manufacturing sector in 1996. The contribution of this model is that it shows how omitting a spatially

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lagged dependent variable can lead to specification bias on the infrastructure parameter, as well as an understatement of the "broader" or "indirect" benefits that would have been apparent with a spatial multiplier.

1.1. Spatial autocorrelation

Spatial econometrics (Cliff and Ord, 1981) has grown in popularity over the past 30 years, and only recently has been widely applied in the area of infrastructure studies.

Spatial autocorrelation occurs when one locality's error term in a regression depends on "neighboring" localities' shocks or innovations, instead of merely being normally distributed with zero mean, constant variance, and zero covariances between observations over time and space. Spatial autocorrelation implies interdependencies among different localities, and in general researchers can accommodate for spatial autocorrelation after conducting a procedure that generates an estimate of the magnitude of the autocorrelation (such as the generalized moments procedure developed by Kelejian and Prucha, 1999). The word "neighboring" is in quotations because the word does not necessarily imply that the neighbor is at a contiguous location. That is, it could imply that locations are similar (or dissimilar) in other ways, such as average incomes of residents, volume of trade between individual locations, distance from each other, or other demographic characteristics.

There are a number of reasons why a model might potentially exhibit spatial autocorrelation. These include possible omitted variables that vary spatially; decisions in one location that are made for entities in other locations; using data that are averaged over different sized areas for different geographic units (Bell and Bockstael, 2000), such as rural versus urban regions; and/or common shocks that spill over across geographic boundaries. An example of the latter could be the weather and its impact on firms' costs or production process. A weather "shock" (for instance, either a storm or a heat wave) hitting some states and impacting production or costs can spill over to an adjacent state, and thus there can be some degree of persistence over geographic space that may lead to spatial autocorrelation.

Ignoring spatial autocorrelation can lead to parameter estimates with higher standard errors than if spatial autocorrelation had not been present. These higher standard errors can translate into *t*-statistics that are smaller than they should be. In other words, ignoring significant spatial autocorrelation can impact hypothesis testing, as researchers might fail to reject a null hypothesis that is actually a false hypothesis. In the context of infrastructure, ignoring spatial autocorrelation can lead a researcher to erroneously accept a null hypothesis that the infrastructure elasticity is equal to zero. Further difficulties arise when ignoring a spatially lagged dependent variable, which can lead to biased parameter estimates, implying inaccurate estimates of infrastructure impacts.

1.2. Spatial lag

The other form of spatial spillovers that can be assessed with spatial econometrics is known as a spatial lag. A spatial lag (or spatial dependence) occurs when the "neighbors" of a particular geographic unit's variable(*s*) are included as explanatory variables in a regression. These spatially lagged variables can be of the dependent variable, as in Kelejian and Robinson (1997) who include in their infrastructure study a spatial lag of output (they call it neighbors' average productivity, or output per worker). Such a spatial lag is often interpreted as the weighted average of other jurisdictions' dependent variable. It is also common for researchers to include a spatial lag of some variable(*s*) other than the dependent variable, such as neighbors' infrastructure (Boarnet, 1998). Ignoring a spatial lag when it should be in a model would lead to biased parameter estimates. In other words, the sign and magnitude of the infrastructure impacts can be affected if spatial lags are ignored.

Thus, addressing potential spatial autocorrelation and spatial lags can have important implications for the estimates of infrastructure impacts. A spatial multiplier incorporates indirect effects on neighboring locations when a particular location changes its infrastructure level. A contribution of this paper is the synthesis of several major studies in the infrastructure productivity literature that incorporate spatial econometrics in the context of transportation. It is postulated that incorporating spatial econometrics leads to more reliable estimates that are significantly different from zero. It is also shown that adjusting one's results for a spatial multiplier can substantially affect the estimates for productivity of infrastructure, through an empirical example of public infrastructure productivity in the US manufacturing sector. This is opposed to the findings of some infrastructure productivity studies, such as Tatom (1993), Hulten and Schwab (1991), and Kopp (2005), which do not incorporate spatial econometrics and postulate that public infrastructure has essentially zero or minimal productive impact. Thus, incorporating wider benefits through spatial econometrics techniques can be important in accurately assessing the impacts of infrastructure.

2. Motivation

Studies in the early infrastructure productivity literature tried to explain the impacts of public infrastructure within a particular geographic location while ignoring the impacts of spillovers across boundaries. Accordingly, much of the empirical productivity literature on public infrastructure is concerned with the question of: by how much is (total factor) productivity enhanced when the stock of public infrastructure increases?

The early empirical productivity literature focused on national-level data using a production function approach of Aschauer (1989), and found a tremendous effect of infrastructure on productivity. Subsequent studies, such as Munnell