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Mutual causality in road network growth and economic development

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ABSTRACT

This paper investigates the relationship between the growth of roads and economic development. We test for mutual causality between the growth of road networks (which are divided functionally into local roads and highways) and changes in county-level population and employment. We employ a panel data set containing observations of road mileage by type for all Minnesota counties over the period 1988 to 2007 to fit a model describing changes in road networks, population and employment. Results indicate that causality runs in both directions between population and local road networks, while no evidence of causality in either direction is found for networks and local employment. We interpret the findings as evidence of a weakening influence of road networks (and transportation more generally) on location, and suggest methods for refining the empirical approach described herein.

1. Introduction

Transportation networks are frequently cited as one of the primary factors affecting patterns of development at the urban and regional level. Depending on the type of change to the network, new links can lead to greater concentration (agglomeration) or dispersal of activities, altering the balance between the location of households and firms at a given level of aggregation. While comparatively more of the work on the relationship between transportation and development has been focused on at the intra-urban level, due in part to the greater abundance of spatial data at this level, there are also important spatial reorganization effects observable at regional and interregional levels.

In this paper, we examine the relationship between road network growth and economic development at the county level in the State of Minnesota over a 20-year period. In particular, we test for the influence of road network growth on the location of population and employment, and vice versa. We divide the road network into two types of roads, highways and local roads (both measured in terms of road length), and evaluate their impact independently given the possibility that they may have differing impacts on the location of population and employment. Granger causality tests are applied to the relationship between road networks and development, using temporal precedence to establish the direction of causality between variables. The longitudinal nature of the data set allows for the examination of longer-term adjustments in response to network growth over time.

The rest of the paper is structured as follows. The next section gives a brief review of the evidence on the relationship between road networks and development. The third section describes the underlying theory and empirical specification of our models, along with hypotheses about the estimated coefficients. It also contains a description of the data set constructed to estimate the model. The fourth section discusses the results of the empirical analysis and their implications regarding the direction of causality between road networks and development. The fifth and final section summarizes the empirical results, assesses the soundness of the methodological approach, and draws some implications for further study.

2. Literature review

Research in transportation and related fields has long recognized the role of transportation networks in shaping locations patterns. The canonical "monocentric" model of urban structure adopted by urban economists identifies transportation costs as a fundamental factor, along with several others (population, income, agricultural land rent), in determining urban spatial structure.

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Empirical tests have confirmed its importance (Brueckner and Fansler, 1983; McGrath, 2005).

Studies of the decentralization of population and employment within and between urban areas have identified patterns of mutual causation between these processes (White, 1999), with transportation network expansion (primarily highways) often assumed to play an intervening role (Garrison et al., 1959; Meyer et al., 1965; Boarnet, 1994). Employment decentralization is often characterized as a process of jobs following workers to suburban locations, facilitated in part by improvements to highway networks which increase the accessibility of these locations (Gordon and Richardson, 1989; Levinson and Kumar, 1994; Glaeser and Kahn, 2001). Isolating causal relationships is difficult in these situations, and the default assumption that is often made that population and employment are jointly determined (Steinnes, 1977) in a multi-equation framework. Other approaches have attempted to address the identification problem associated with the endogeneity of transportation investment using instrumental variables (IV). For example, a study of the effect of urban highway growth on central city population decline by Baum-Snow (2007) used planned segments of the interstate highway system (including unbuilt segments) as a source of exogenous variation to estimate its effect on population decline in a single-equation model. However, the plausibility of this choice of instrument has been questioned (Cox et al., 2008), and there have been few other published examples of the identification of possible instruments.

The location of residences and places of employment and the role that transportation networks play in shaping them have implications for specific types of policy measures. Policies to encourage jobs-housing balance within local jurisdictions (Cervero, 1989, 1996) have been advocated on the assumption that greater balance between concentrations of employment and housing will lead to greater self-containment of commute and non-commute trips, while also balancing directional network flows. Given the role of transportation networks in changing the relative attractiveness of locations, this would seem like a plausible direction to pursue. Yet evidence on trends in urban form within many US cities indicates that a certain amount of "balancing" at local levels takes place over time even in the absence of explicit policy direction (Giuliano, 1991; Cervero, 1996).

Moreover, many transportation networks, including those in urban areas, are reaching a state of maturity with few new links being added and only modest capacity additions identified in most regional plans. Theories and historical evidence regarding the deployment of transportation networks suggest that the few new links likely to be built at this more mature stage, illustrated in Fig. 1, will probably exert less influence on growth and location patterns (Garrison and Levinson, 2006).

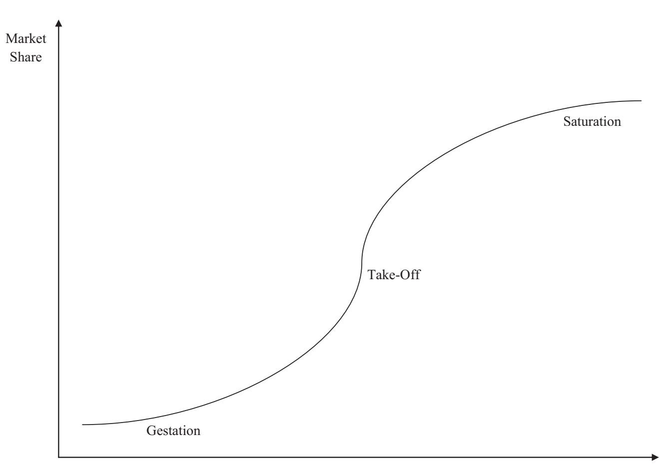

Fig. 1. Deployment curve for transportation networks.

Mutual causality between transportation network growth and location choice has also been at the heart of a number of studies attempting to explain historical patterns of development. Several of these studies have emphasized the influence that specific modes of urban travel have had on development patterns at a particular time in history. For example, Levinson (2008) identified a feedback process between the growth of underground and surface rail networks in London and population density at the borough level during the late 19th century. Another study by King (2011) examined the relationship between the growth of the New York City subway network and patterns of residential and commercial land use. Results indicated that the growth of the network did not precede development, but rather that it served already-emerging residential areas. In contrast, a study of the co-evolution of residential development and streetcar network growth in the Minneapolis-St. Paul, Minnesota region during the early 20th century found evidence that the growth of the streetcar network led residential development within the region (Xie and Levinson, 2010). In each of these studies, the method of Granger causality was used as the identifying assumption for establishing a causal link between network growth and urban development.

Such methods have also been adopted at broader geographic scales to investigate questions of causality between network growth and regional development. For example, Carlino and Mills (1987) expanded an equilibrium model of population and employment location designed for urban areas to a national scale to identify the causes of county-level growth in the United States during the 1970s. They found evidence that county-level interstate highway density was positively associated with both population and employment density. Another study of major corridor-level highway development and population growth by Chi (2010) used minor civil division-level (city or township) census data on population change in the state of Wisconsin during the 1980s and the 1990s to identify the longer-run influence of highways. Results indicated that the strongest impacts of highway development on population growth occurred in suburban areas, while impacts were weaker in rural areas and not statistically significant in urban areas. More frequently, studies that have focused on a regional or larger scale have identified employment as the critical measure of development. Recent work by Jiwattanakulpaisarn et al. (2009, 2010) examined causality in the relationship between state highway networks and employment, both in terms of total employment and sector-level disaggregation, using a panel vector autoregressive (VAR) framework. Applying this framework to a panel of US states from 1984 to 1997, they find evidence of temporal relationships between changes in state highway network capacity and changes in employment, though certain sectors tend to be impacted more positively (e.g. services), while others are negatively impacted (manufacturing).

Of note, many studies of the relationship between transportation infrastructure and economic growth, including those cited above and the voluminous economic literature on public capital and economic growth, use fairly aggregate measures of the stock of highway infrastructure (measured either in terms of discounted economic value, network length, network capacity, or others). This is in part due to the difficulty of obtaining such measures (in the United States, at least), especially for longer time series, at more disaggregate levels. Those studies that do, including the one by Carlino and Mills (1987), tend to focus on shorter time horizons such as decennial changes which can be measured via published census data. The present study addresses some of these issues by using a 20-year panel of county-level network data furnished by a state department of transportation to probe the relationship between changes in transportation networks and growth in