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Spatial economic impact of road and railroad accessibility on manufacturing output: Inter-modal relationship between road and railroad

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ABSTRACT

Despite the numerous attempts to quantify the benefits of transportation investments, little attention has been given to the variation of marginal economic impacts of the investment due to the interaction with existing transportation networks. This paper analyzes the spatial economic impacts of road and railway accessibility levels on manufacturing output, focusing on substitution and complementarity of the intra- and the inter-modal relationship. By estimating Translog production functions, we find that the improvement in railroad accessibility increases the marginal value added of local manufacturing industries associated with the change in road accessibility. The marginal value added with respect to the change in railroad accessibility increases by the level of railroad accessibility, resulting in increasing returns to scale. However, road accessibility can positively influence the marginal value added only with respect to the railroad variables, holding decreasing returns to scale. This implies that there is not a substitutive but a complementary relationship between the two transportation modes in terms of manufacturing output.

1. Background

Over the past few decades, contribution of transportation investment to private output has received considerable attention in regional economics. Reduced form econometric models (e.g., production function) have been widely adapted in relevant studies due to the advantage of the simple logic and easy interpretation. However, the estimates of the benefit tend to vary greatly in the literature, often showing insignificant or even negative economic impacts. Recently, Melo et al. (2013) and Elburz et al. (2017) conducted a meta-analysis of previous studies on the output elasticity of transportation infrastructure. They found that the investment-specific factors (e.g., transportation mode and country coverage) and research design (e.g., estimation method, model specification, input and output measurement, data type, geographical scope, and research period) were the major sources of the variation in the estimates of economic impacts of transportation investments.

However, there is still a lack of consideration for the interaction between the new and existing transportation infrastructure, potentially affecting the marginal benefit from transportation investment. More attention should be paid to the interaction between transportation infrastructures not only from the academic perspective but also from the policy side; project prioritizations are often required due to SOC budget constraints, and the choice of priority projects should be based on the complementary or substitutive relationship between the project alternatives (and that with existing infrastructure). Furthermore, network-wide effects of the investment should be appraised because each segment of transportation facility constitutes a broader network (Banister and Berechman, 2001).

This paper analyzes the spatial economic impact of road and railroad accessibility on manufacturing output, taking into account the interaction between road and railroad facilities. Our contributions are twofold. First, we shed light on the changing nature of the marginal benefit from road and railroad infrastructure depending on local attributes. This marginal value added is derived based on an estimation of a Translog production function specifying an interaction term between road and railroad accessibility as well as square terms of the two different accessibility variables. By investigating the substitution and complementarity between road and railroad in production activities, we aim to disentangle two main forces determining the marginal benefit from transportation investment: 1) diminishing returns to transportation capital stock and 2) increasing returns due to efficiency gain from the use of integrated transportation network.

Second, we use road and railroad accessibility measures instead of the quantity of transportation capital stock. Being a performance measure, an accessibility index better captures the quality of transportation network, represented by travel speed. It also accounts for the spillover of investment effects through networks, which is rarely

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addressed using investment variables. Furthermore, substantial decline in freight transportation cost increases relative importance of rapid transportation for the flow of knowledge and human interactions (Glaeser and Kohlhase, 2004), justifying the use of accessibility index as a measurement of transportation improvement. However, despite the growing academic interest in accessibility measures, applications of accessibility indexes for the estimation transportation investment impacts remain sparse (Suárez, 2007; Gutiérrez et al., 2010). The accessibility index applied in this paper is based on the shortest inter-zone travel time using full range of road and railroad networks and time decay functions estimated using actual travel data.

Our empirical analysis focuses on 24 manufacturing industries in 239 municipalities in South Korea. The rest of this paper is organized as follows. Section 2 briefly reviews earlier works discussing the variation of marginal economic impact of transportation investment. Section 3 describes our methods composed of the development of accessibility indexes and the estimation of spatial economic impact of road and railroad accessibility. Section 4 reports the analysis results and discusses the local variation in the marginal economic benefit from road and railroad accessibility. The final section summarizes our key findings and discusses further research avenues.

2. Literature review

Several studies have suggested that marginal economic benefit from transportation investment is affected, negatively in general, by the endowment of transportation capital (Rietveld and Nijkamp, 1993; Vickerman et al., 1999; Canning and Bennathan, 2000; Suárez, 2007). However, the law of diminishing returns to transportation infrastructure does not always upheld, because the benefit from better accessibility might cancel out the disadvantage from diminishing marginal returns (Melo et al., 2013). Given that transportation of goods and people is completed using a joint network of different means of transportation in many cases, inter-modal relationship might affect marginal gain from transportation investment. If the relationship between two different transportation modes is complementary, a synergetic effect might emerge due to further improvement in accessibility, achieved by the use of integrated transportation networks. In contrast, as intra-modal substitutability increases, it is more likely that "diminishing marginal returns" will dominate.

Empirical findings from the literature suggest that the roles of roads and railroads can be either substitutable or complementary, depending on the factors including technology level, travel mileage, trip purpose, and regional background. Oum (1979) demonstrated that the inter-modal relationship in Canadian freight transportation services has changed from complementary to substitutive since the 1960s due to substantial growth of highway transportation technology. However, inter-modal relationships could become affected by the availability of alternative transportation modes. By estimating a Scandinavian freight demand model, Rich et al. (2011) showed that "structural inelasticity," referring to the exclusive use of a single mode of freight transportation (trucks, in particular) due to the lack of alternative modes (e.g., rail and ships), reduced the inter-modal substitutability. While the share of truck-dominated freight transportation tended to decline by shipping distance, the sensitivity to distance varied across commodity groups (Rich et al., 2011; Nolan and Skotheim, 2008). Shifts to other modes (e.g., rail and ships) were distinct in the shipment of low-value goods and bulk products, whereas the mode choices for high-value commodities were less dependent on travel distances. Meanwhile, inter-modal substitutability in production might vary across regions (Bianco et al., 1995). In this case, differences in geographical constraints or industrial structure could be a potential source of this variation.

Urban agglomeration could be another important factor explaining the variation in marginal benefits from transportation infrastructure. Given the logic that transportation improvements increase the "effective density" of economic activities (Graham, 2007), spatial concentration of economic activities might work equivalently with the increase in transportation accessibility. Inverted U-shaped relationship numerically explained in Tabuchi (1998) supported this idea. When interregional transportation costs become low enough, the diseconomies of urban scale (e.g., rent competition) nullify the agglomeration benefit; consequently, firms and workers disperse. From this perspective, the advantage derived from market proximity could be easily replaced by the easy access to market using transportation networks. For example, the increase in agglomeration costs would attract firms into locations with lower densities of economic activities but higher levels of transportation accessibility.

From the literature above, we can hypothesize that marginal returns to transportation accessibility depend on the accessibility level of two transportation modes (i.e., road and rail) as well as the intensity of urban agglomeration. The marginal benefit from transportation accessibility would decrease if the level of spatial concentration of economic activities increased. However, the direction of marginal effect of the accessibility would vary by the level of transportation accessibility and the inter-modal relationship of the study area. If the transportation network is highly saturated in terms of the accessibility, and the roles of different transportation modes are substitutable, relatively little gain from the improvement in transportation accessibility is expected.

3. Methods

3.1. Measurement of road and railroad accessibility

The definition of accessibility varies depending on the purpose of trip and the type of user, but many of these variations are closely linked with "potential of opportunities for interaction" (Hansen, 1959). In particular, when the economic impacts of transport investment is of interest, "economic potential," the volume of economic activity between regions, after traveling cost (or distance) has been taken into account (Dundon-Smith and Gibb, 1994), has been commonly used to illustrate the interaction between spatially remote areas (Rosik et al., 2015). The generalized description of the indicator is given by the following formula:

$$\mathrm{Acc}_i = \sum_j M_j f(C_{ij}) \tag{1}$$

Acc_i: Accessibility of an origin place.

M_j: Mass of a destination place.

$f(C_{ij})$: Decay function of the generalized traveling cost from an origin to a destination place.

3.1.1. Pulling force of a destination

In general, the mass of a destination is measured by its population, implying that the attractiveness of a place depends on its population size. However, travel demand from an origin to a destination might not be fully accommodated if the handling capacity of transportation facilities connecting them is below the level of the destination's pulling force. The case is rather uncommon with road transportation where the modal share of public transportation is relatively low. However, limited load capacity of a vehicle and/or daily number of trains might matter to rail travelers. This could particularly affect those heavily relying on conventional rail services because the dual operation with high speed rail (HSR) often degrades the service quality of conventional rails (e.g., daily number of trains) (Givoni and Banister, 2012). Thus, physical and operational constraints can be overlooked in the measurement of the "potential of opportunity for interaction between spatially remote regions" using railroad transportation. In this study, dual approach is taken for the measurement of the mass of a destination in Eq. (1). It is measured by the destination's population for the calculation of road accessibility; however, the minimum of the destination's population and