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Efficiency or Equity? Determinants of Regional Allocation of Infrastructure Investment in the Republic of Korea*

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We used a structural model to determine which aspects of efficiency and equity criteria were advocated in allocating investment in transportation infrastructure by region in the Republic of Korea during the period of 2001–2014. The estimation by the generalized method of moments indicated that the country's regional allocation of public investment favored equity enhancement rather than efficiency gain. Empirical findings also include evidence of the substitutionary relationship between the investments by the central and regional governments, as well as the excess capital stock of transportation infrastructure compared with the optimum. The infrastructure needs and regional financial conditions had limited effects on the past allocation of investment. Political influence was exerted with respect to electoral productivity rather than partisanship.

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I. Introduction

Many policies and studies on the regional allocation of public investment have emphasized efficiency from an economic point of view. A balanced regional development (BRD) to narrow the gap in regional development has also been frequently discussed in the context of equity among regions. The annual sectoral reports on the Republic of Korea (ROK)'s medium-term infrastructure plans to

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invest and set the overall policy direction, together with the national fiscal management plan (NFMP), have consistently presented a policy direction emphasizing efficiency over several years. At the same time, BRD is also recognized as "an important policy task as the gross domestic product (GDP) share of the Seoul Metropolitan Area has reached 50% and the living conditions in underdeveloped areas have not significantly improved" (Working Group of SOC Field in National Finance Operation Plan, 2015, p. 72).

Although an improvement in efficiency is expected to be achieved by enhancing cost-effectiveness, equity is in many cases questionably recognized as the leveling of key indicators in regions, including population, income, fiscal power, and infrastructure. Thus, to achieve BRD, the regional allocation of public investment that bridges the regional development gap is often emphasized. For example, the preliminary feasibility study (PFS) of the ROK to proactively review the technical efficiency of large-scale public investment projects accommodates the "BRD analysis" component in terms of equity, thereby giving additional points when investing in underdeveloped regions. Adopting such a scheme aims to consider the level of regional gap in the evaluation (Korea Development Institute, 2008).

A trade-off exists among policies to increase the economic effects of public investment projects with an emphasis on efficiency and policies to enhance the redistribution effect in terms of equity. If efficiency is highlighted in conducting the cost-benefit analysis, then the investment may be concentrated in areas with a large population and production capacity due to their advantages in terms of demand and further potential benefits. By contrast, giving priority to equity can result in inhibiting productivity. Therefore, which aspects of equity and efficiency have been emphasized in the past regional allocations of public investment must be empirically examined, and implications must be drawn to use as a basis for judging future policy directions of the ROK. However, empirical research considering efficiency and equity for the regional distribution of public investment in the ROK can be rarely found. Two noteworthy attempts are those by Ahn and Kim (2006) and Lee and Choe (2010).

First, Ahn and Kim (2006) conducted simulations on the regional allocation of transportation infrastructure using the methodology of Yamano and Ohkawara (2000). They compared the changes in economic growth and income gaps between regions according to three regional allocation schemes for the same amount of investment. The three schemes are (a) "allocation for efficiency," in which the investment is allocated in the order of the marginal productivity of regional transportation infrastructure capital stock; (b) "allocation for equity," in which the investment is allocated in proportion to the amount of labor input in the region; and (c) "allocation for equality," which distributes the same investment in all regions. The simulation results demonstrated that the magnitudes of the effects of these schemes on the economic growth are in the order of the allocation for efficiency, equity, and equality, whereas the lowering effect on the Gini index is in the opposite order. Moreover, the transportation infrastructure investment policy in the ROK lies between the "allocation for equity" and "allocation for equality."

Second, Lee and Choe (2010) estimated the regional production function to obtain the marginal productivities of public and private capitals by region. They found that the gap between the marginal productivities of regional public capitals is considerably greater than that of regional private capitals and that the coefficient of variation also increases gradually over time. In addition, public capital is formed more in the regions where per capita production is smaller. On the basis of these results, they argued that efficient regional allocation of public capital had not been executed and that the distribution of public capital was used as a major means to improve spatial equity.

Previous studies have adopted methods for comparing simulation results that are difficult to realize or methods for comparing the private sector with the public sector by estimating a simple production function. These methods have limitations in that the government's decision on the regional allocation of public investment is not directly modeled, and the actual influences of factors affecting the investment decision are not found.

To overcome the limitation of the previous studies and avoid a misspecification of arbitrarily set reduced-form models, this study attempts to estimate a structural model based on economic theory, which explicitly accommodates the government's investment decision. Consequently, it seeks to empirically examine which aspects of efficiency and equity have been emphasized in the regional allocation of public investment in the ROK and draw policy implications. The main contribution of this study is that it is the first attempt to do so using the data of the ROK.

Among existing studies establishing a structural model, de la Fuente (2004) examined to what extent regional disposable income and redistribution are considered in allocating resources by comparing observed regional infrastructure capital stock. To determine which aspect of efficiency and equity is emphasized, Castells and Solé-Ollé (2005) directly modeled the trade-off between them in the social welfare function that the policy maker wants to maximize.

How political considerations influence the allocation of investment resources by region has also attracted attention. Representative examples of studies on this topic using structural model include Knight (2004) and Cadot et al. (2006), which empirically determined a local politician's influence on the central government's decision in relation to investing in transportation infrastructure projects from a political economy perspective. In addition, Bell and Fageda (2009) revealed the decision maker's incentive to pursue private (political) interests in allocating investment on airports by testing a structural model.

The scope of this study is limited to understanding the determinants of the regional allocation of investment in transportation infrastructure in the ROK over the observable period from 2001 to 2014. Moreover, the study aims to focus on the trade-off between equity and efficiency as a criterion considered at the allocation stage. This study does not intend to evaluate changes in efficiency or equity as an outcome of distribution of transportation infrastructure among regions. To achieve this objective, the influence of the transportation infrastructure on production and consumption should be evaluated using, for example, a spatial econometric analysis embracing the interregional network, border, and spillover effects due to the nature of transportation infrastructure. Recent existing studies examining the effect of public investment considering the interaction between regions using the spatial weight matrix include Boarnet (1998), Cohen (2010), Cohen and Paul (2004), Delgado and Álvarez (2007), and Yu et al. (2013). However, these types of analysis are outside the scope of the present study.

A further interesting empirical question is whether the relationship between the central government and the regional government's public infrastructure investment is complementary or substitutionary in the context of the ROK. Given the capacity to fund large-scale infrastructure projects and the limitation of data, we considered the subnational governments at the "regional" level (i.e., the metropolitan cities and provinces) instead of the "local" governments (i.e., municipalities) throughout this study.

For interregional roads and railroads, rapid transits, and some port facilities, investment costs are shared at a fixed rate by the central and regional governments in the ROK, and, accordingly, their investments may be complementary. However, if a project funded by the national treasury, such as a highway or a national road, is implemented in a certain area, then the road traffic demand in that area is covered without the regional government budget. This scenario results in reducing the investment by the regional government and further constituting a substitutionary relationship between the investments by the central and regional governments. Even in the same situation, these investments can be complements when the construction of a national road requires the building of connecting roads to be funded by the regional government. The results of previous empirical studies on this topic are mixed. Castells and Solé-Ollé (2005) demonstrated a substitutionary relationship between the central and regional governments' investments in transportation infrastructure in Spain. By contrast, Aronsson et al. (2000) found that the public expenditures of Swedish regional (county) and local (municipal) governments are complements through the estimation of conditional demand functions.

Typically, politicians want to attract large-scale infrastructure in their own regions due to the fact that the nature of infrastructure is site-specific and thus increases the constituency. For example, in the case of facilities covered by the national treasury in particular, the benefits are concentrated in the region, whereas the burden of costs is spread nationwide. Therefore, political influence on the regional allocation of infrastructure investment is almost inevitable and must be explicitly considered in the analysis by introducing specific variables.

The selection of political variables to consider in allocating resources to the region can refer to existing political and economic studies, such as Levitt and Snyder (1995), Cadot et al. (1999, 2006), Case (2001), Dahlberg and Johansson (2002), Borck and Owings (2003), Johansson (2003), Solé-Ollé and Sorribas-Navarro (2008), and Arulampalam et al. (2009). The particular emphasis in these studies is "electoral productivity" and "partisanship." The former is the view that politicians have incentives to allocate more resources where marginal benefits that can be obtained in elections through public investments are relatively high. The latter point of view is that politicians have an incentive to solidify political support by increasing the allocation to areas where they already receive high support.

In addition to political variables, other variables that can influence infrastructure investment allocation decisions include those indicating the infrastructure need and regional financial conditions. The former refers to the regional utilization of infrastructure by type (i.e., roads, railroads, airports, and ports), whereas the latter refers to regional tax revenue, debt, and financial power, among others.

The estimation results using economic, political, and financial variables can be summarized as follows. (a) The regional allocation of investment in transportation infrastructure has been made with an emphasis on equity rather than efficiency in the ROK. (b) The capital stock of transportation infrastructure in the country seems to have accumulated excessively during the analysis period. (c) The allocation of transportation infrastructure by region has not been made based on the demand of users. (d) There exists a political influence on the regional allocation of transportation infrastructure in terms of electoral productivity. (e) The allocation of transportation infrastructure has not sufficiently considered regional financial conditions.

The remainder of this paper is structured as follows. Section 2 introduces the model accommodating the regional production and the central government's social choice in finding the optimal infrastructure stock. Section 3 presents the setups and strategies for estimating the model. Section 4 describes three types of variable (i.e., economic, political, and fiscal) and data used in estimation. Section 5 discusses the estimation results. Finally, Section 6 is devoted to concluding remarks with policy suggestions.

II. The Model

Most of the settings in the present study's model follow those of Castells and Solé-Ollé (2005). However, for the sake of completeness of the study and given that some settings (political influence, in particular) need to be modified to suit the reality of the ROK, we introduce the entire model. Settings different from those used in Castells and Solé-Ollé (2005) are explicitly notified.

"Infrastructure," hereafter, specifically refers to transportation infrastructure, including roads, railroads, airports, and ports. We set this scope because transportation infrastructure is a representative type of infrastructure, and because we intended to exclude from the analysis the unique characteristics of other infrastructures not destined for the movement of resources.

2.1. Production Function

The production function Y_{it} in region i at time t is defined as

$$Y_{it} = A_{it}F(K_{it}, L_{it}, T(X_{it}, Z_{it})), \tag{1}$$

where K_{it}, L_{it}, and T_{it} denote the private capital excluding transportation, labor, and transportation service, respectively. The transportation service is determined by the service flow provided by public infrastructure Z_{it} and transportation input X_{it}. The Hicks-neutral technology level is denoted as A_{it}.

Public infrastructure can be understood as a concept that encompasses the infrastructure necessary for all transportation services required for a firm's logistics activities but typically refers to transportation infrastructure, such as roads, railways, ports, and airports. Therefore, the amount of traffic input required by firms in region i at time t for logistics X_{it} indicates the stock of commercial vehicles and containers for maritime transportation for each region. Moreover, the flow of services provided by the public infrastructure will depend on how well the transportation infrastructure is equipped and how frequently it is used. In view of the congestion of transportation infrastructure, the services provided by public infrastructure Z_{it} are affected by the size of the public infrastructure C_{it} and its utilization level U_{it}. We also considered that infrastructure construction costs (ς_i) may differ across regions due to some intrinsic and time-invariant factor (e.g., orography). We assumed for the moment a flexible relationship among these variables, $Z_{it} = Z((C_{it} / \varsigma_i), U_{it})$, imposing only that $Z_C = \partial Z / \partial C > 0$ and $Z_U = \partial Z / \partial U < 0$ (Castells and Solé-Ollé, 2005, p. 1168). This assumption implies that the amount of service increases with the size of the transportation infrastructure, considering the unique characteristics of a region; however, it decreases as the utilization level by other users increases. Therefore, transportation infrastructure is not treated as a pure public good, but rather as having characteristics of weak non-rivalry in terms of congestion.

Here, $T(\cdot)$ may be defined by considering the interaction between regions, such as the network effect of traffic service or the spatial ripple effect. In other words, the services provided by public infrastructure can be affected not by only the size and level of use in a given area but also in the adjacent areas. As commonly done in the spatial econometric analysis, we can think of a setting for each region $i \in \{1,2,\dots n\}$ that substitutes Z_{it} by defining $Z'_{it} = w_i Z_t$, in which $Z_t := (Z_{it},\dots,Z_{nt})$ and w_i is an $(1\times n)$ spatial weight vector whose ith element and elements denoting those sharing the border with region i are typically assigned the value of 1, and 0 otherwise. However, given the reality of the ROK's relatively small territory and use of transportation networks, considering the influence of only adjacent areas is inappropriate, and such settings were not considered in this study to prevent the heavy burden of empirical analysis. Furthermore, as will be discussed in more detail later, variables such as traffic and logistic volumes in regions were used in the empirical analysis, because no appropriate variables represent public infrastructure services. When modeling interactions between regions, whether these variables correctly represent regional interactions is unclear. Nevertheless, the lack of explicit modeling of interactions between regions is a limitation of this study, and further analyses in this area will be left as future research tasks.

Firms are under complete competition, and their production function has the characteristic of constant return to scale for private input factors. By summarizing the above assumptions, the effect of an increase in the size of the public infrastructure in Equation (1) on production is obtained as follows:

$$F_C = F_Z Z_C \frac{1}{\varsigma_i} = \left(\frac{F_Z Z_{it}/F}{F_X X_{it}/F}\right)\left(\frac{F_X X_{it}}{F_{it}}\right)\left(\frac{Z_C C_{it}}{Z_{it}}\right)\frac{1}{\varsigma_i}\frac{F_{it}}{C_{it}} = \omega_{it} S_{it}^X E_{it}^C \frac{1}{\varsigma_i}\frac{F_{it}}{C_{it}},$$

where $F_V = \partial F/\partial V$ for $V \in \{C,X,Z\}$. That is, the factors constituting F_C include the ratio between the output elasticity of public infrastructure services and the output elasticity of private transportation inputs $\omega_{it} := \frac{F_Z Z_{it}/F}{F_X X_{it}/F}$, the share of traffic to production volume $S_{it}^X := F_X X_{it}/F_{it}$, the elasticity of transportation services in public infrastructure stock $E_{it}^C := Z_C C_{it}/Z_{it}$, and the cost of building public infrastructure specialized for the region $1/\varsigma_i$. Here, $\omega_{it} > 0$ can be inferred because the use of transportation infrastructure will be more frequent in industries that require more vehicles, such as logistics and passenger business. For the analysis, we assumed that T_{it} is separable from K_{it}, and L_{it} has the same Cobb–Douglas production function in all regions. Then, given $\omega_{it} = \omega$, the following equation can be obtained:

$$F_C = \omega S_{it}^X E_{it}^C \frac{1}{\varsigma_i}\frac{F_{it}}{C_{it}}. \tag{2}$$

2.2. Social Choice Rule

The central government has the following social welfare function (SWF) with constant elasticity of substitution:

$$W_t = (\sum_i N_{it} \Psi_{it} (Y_{it} / N_{it})^{\phi})^{1/\phi}, \tag{3}$$

where N_{it} denotes the population in region i at time t; thus, Y_{it} / N_{it} is the production per capita. The parameter $\phi \in (-\infty, 1]$ indicates the government's aversion to inequality in regional production, which is of the main interest of this study. Thus, the smaller the value of ϕ is, the greater the aversion to inequality among regions will be. For example, if $\phi \to -\infty$, then the government pursues pure equity. By contrast, if $\phi = \infty$ yields $W_t = Y_t = \sum_{i=1}^{n} Y_{it}$, then the government's interest is to maximize efficiency. Particularly, the SWF is Cobb–Douglas if $\phi = 0$. Parameter Ψ_{it} can vary by region depending on the consideration of efficiency and equity. If only equity is considered, then it has the same value in all regions as $\Psi_{it} = \Psi_t$. The parameter Ψ_{it} can be interpreted as a political consideration when allocating budget, as it reflects the characteristics of the region in addition to the government's consideration of efficiency and equity in public investment (for more detailed explanations, see Castells and Solé-Ollé, 2005, pp. 1171–1172).

2.3. Optimal Infrastructure Stock

The government determines the level of regional allocation level of transportation infrastructure that maximizes the SWF (3). In so doing, the effect of transportation infrastructure expressed by Equation (2) on the regional production and the following budget constraint should be considered:

$$\sum_{i=1}^{n} I_{it} \leq R_t, \tag{4}$$

where I_{it} denotes the investment in region i at time t, and R_t is exogenously given investment resources for transportation infrastructure at time t.

By taking a partial derivative of the SWF (3) with respect to the investment by region under Constraint (4), we can obtain the following first-order condition:

$$\frac{\partial W_t}{\partial (Y_{it} / N_{it})} \frac{\partial (Y_{it} / N_{it})}{\partial C_{it}} \frac{\partial C_{it}}{\partial I_{it}} - \lambda_t = 0, \text{ for all } i, \tag{5}$$

where λ_t denotes the marginal cost of public revenue. By substituting Equation (2) into Equation (5) for $\frac{\partial (Y_{it}/N_t)}{\partial C_{it}}$, differentiating the SWF (3) with respect to the output per capita solving $\frac{\partial W_t}{\partial (Y_{it}/N_{it})}$, and using $\frac{\partial C_{it}}{\partial I_{it}} = 1$, we can rearrange and rewrite equation (5) as

$$\frac{\omega S_{it}^X E_{it}^C}{\varsigma_i (C_{it}/Y_{it})} = \lambda_t^* \left(\frac{(Y_{it}/N_{it})^{1-\phi}}{\Psi_{it}} \right), \text{ for all } i, \quad (6)$$

where $\lambda_t^* = \lambda_t W_t^{(1-\phi)/\phi}$. The left side of the above equation represents the marginal production of public infrastructure, whereas the right side represents the marginal cost of public infrastructure investment. Interestingly, the marginal cost does not depend only on the marginal cost of public resources λ_t^*. The more the government emphasizes regional equity, the higher the relative marginal cost of public infrastructure investment in wealthier areas compared with poorer ones. Moreover, the marginal cost of the politically important area (high Ψ_{it}) is low (see Castells and Solé-Ollé, 2005, p. 1172 for more details).

Finally, after taking the logarithm in Equation (6) and rearranging it, we can obtain the following equation for the optimal level of public infrastructure stock in each region C_{it}^*.

$$\ln C_{it}^* = B_{it} + \phi \ln Y_{it} + (1-\phi)\ln N_{it} + \ln S_{it}^X + \ln E_{it}^C + \ln \Psi_{it}, \quad (7)$$

where $B_{it} := \ln \omega - \ln \varsigma_i + (1-\phi)/\phi \ln W_t - \lambda_t$.

III. Setups and Strategies for Estimation

3.1. Individual and Time Effects

Estimation of the terms in Equation (7) is highly difficult. To solve this problem, we controlled $\ln W_t$ and λ_t, which do not differ by region, by the time effect f_t. Moreover, the term $\ln \varsigma_i$, which shows regional differences, was controlled by including the individual effect f_i due to the limit of finding a suitable representative observation. Accordingly, the term B_{it} can be rewritten as

$$B_{it} = f_i + f_t + \varepsilon_{it}, \quad (8)$$

where ε_{it} is an error term with mean zero.

Castells and Solé-Ollé (2005) considered additional individual and time effects by considering the different institutional characteristics of each region and the existence of earmarked investment funds allocated to the promotion of specific projects. However, such an additional consideration seems unnecessary due to the characteristics of the institutions in the ROK. More precisely, Castells and Solé-Ollé (2005, p. 1173) used a dummy variable to distinguish between regions that received national treasury support and those that did not. In the ROK, all regions are supported at the metropolitan and provincial levels.

3.2. Dynamics

Two assumptions were made to reflect the government's investment behavior in reality. First, at time t, the government's decision to allocate regional public investment is made according to the expected value of each variable at time t formed in the previous period ($t-1$). Second, reflecting the new status of regions in investment allocation immediately after the regional characteristics change is difficult for the government (Castells and Solé-Ollé, 2005, p. 1173).

According to the first assumption, the expected value of the economic variables in Equation (7) at time t is assumed to be equal to the value of those at time ($t-1$). Thus, the actual government investment decisions are based on available data from the previous period in that these variables are observed every time period.

The second assumption implies that adjusting capital stock to an optimal level in the long run has a considerable cost, and the following equation is assumed to reflect this:

$$\ln C_{it} = \ln C_{it-1} + \rho(\ln C_{it}^{*} - \ln C_{it-1}), \tag{9}$$

where the public infrastructure capital stock at time t ($\ln C_{it}$) is the sum of the capital stock at the previous ($t-1$) period ($\ln C_{it-1}$) plus a portion ρ of the difference between the optimal capital stock at time t ($\ln C_{it}^{*}$) and the capital stock at the previous period (Castells and Solé-Ollé, 2005, p. 1174). Again, Equation (8) can be expressed as a linear combination of the optimal capital stock of this period and the capital stock of the previous period as $\ln C_{it} = \rho \ln C_{it}^{*} + (1-\rho)\ln C_{it-1}$. Hence, even if short-term investment is increased, the optimal capital stock cannot be reached immediately, and the pace of adjustment varies depending on the level of capital stock in the previous period.

Now, using the first assumption above, letting the predicted value of the political variables be Ψ_{it}^{e}, and substituting Equations (8) and (9) into equation (7), the unobservable optimal public infrastructure capital stock can be replaced with the observable public infrastructure capital stock, and the following can be obtained:

$$\begin{aligned} \ln C_{it} = (1-\rho)\ln C_{it-1} + \rho\phi \ln Y_{it-1} + \rho(1-\phi)\ln N_{it-1} + \\ \rho \ln S_{it-1}^{X} + \rho \ln E_{it-1}^{C} + \rho \ln \Psi_{it}^{e} + f_i + f_t + \varepsilon_{it}. \end{aligned} \tag{10}$$

Equation (10) is in the form of a dynamic panel model that includes a lagged dependent variable in the set of explanatory variables. If this equation is estimated by the ordinary least squares (OLS), then a bias may occur (Arellano and Bond, 1991). Therefore, the first difference equation of Equation (10) will be used for estimation as shown below, and the precautions will be discussed in more detail later:

$$\Delta\ln C_{it} = (1-\rho)\Delta\ln C_{it-1} + \rho\phi\Delta\ln Y_{it-1} + \rho(1-\phi)\Delta\ln N_{it-1} + \rho\Delta\ln S^{X}_{it-1} + \rho\Delta\ln E^{C}_{it-1} + \rho\Delta\ln\Psi^{e}_{it} + f_t + \Delta\varepsilon_{it}. \quad (11)$$

3.3. Political Influence

Dealing with political influence in the context of the political environment in the ROK is the main difference in the present study's model setup compared with Castells and Solé-Ollé (2005). The political influence of the election can include not only the change of political variables according to the election results but also the influence of the election cycle (four years in the case of general elections). Moreover, only the data of the year at the time of the election (k) can be observed. Furthermore, in view of the hierarchy of the ROK's political powers, we considered the influence of the members of the National Assembly who deliberate and decide the budget of the central government and thus typically have the greatest influence on the allocation of investment in regional infrastructure. In this regard, the expected value of the political variable is set as

$$\ln\Psi^{e}_{it} = (\textstyle\sum_{s=0}^{3}\beta_s d_{st})\ln\Psi_k, \quad (12)$$

where s represents the difference from the coming election year (in years), and $s=0$ denotes the election year. In addition, d_{0t} is a dummy variable having a value of 1 if t is an election year, and 0 otherwise. For $s=1,2,3$, d_{st} is a dummy having a value 1 if t is ahead of the next election s years, and 0 otherwise. Each β represents the level of political variables according to the election cycle whose value is assumed to be non-decreasing as the election approaches (i.e., $\beta_s - \beta_{s+1} \leq 0$ for $s=0,1,2$.) The first-order differential equation of Equation (12) is then obtained as follows:

$$\Delta\ln\Psi^{e}_{it} = \beta_3 d_{3t}\Delta\ln\Psi_k + (\beta_3-\beta_0)d_{3t}\ln\Psi_{k-1} + [(\beta_0-\beta_1)d_{0t} + (\beta_1-\beta_2)d_{1t} + (\beta_2-\beta_3)d_{2t}]\ln\Psi_k. \quad (13)$$

To alleviate the heavy burden of the estimation in case this is reflected in Equation (11) as it is, the additional effect of the political influence according to the election cycle will be examined. That is, if a relationship with $\beta_s - \beta_{s+1} =: \beta$ is established for $s = 0,1,2$, then Equation (13) becomes

$$\Delta \ln \Psi^e_{it} = \beta_3 d_{3t} \Delta \ln \Psi_{k} + 3\beta d_{3t} \ln \Psi_{k-1} + \beta(d_{0t} + d_{1t} + d_{2t}) \ln \Psi_{k} .$$

Furthermore, if the political influence is the same regardless of the election cycle, $\beta_s - \beta_{s+1} = 0$ for $s = 0,1,2$, and Equation (13) is simply expressed as

$$\Delta \ln \Psi^e_{it} = \beta d_{3t} \Delta \ln \Psi_{k} .$$

Therefore, in the estimation process, the null hypothesis of $H_0 : \beta_s - \beta_{s+1} = \beta$ for $s = 0,1,2$ was tested by substituting $\Delta \ln \Psi^e_{it}$ in Equation (10) for $(d_{3t} \Delta \ln \Psi_{k}, d_{3t} \ln \Psi_{k-1}, (1 - d_{3t}) \ln \Psi_{k})$. At this time, whether $\beta = 0$ was also of interest.

3.4. Central and Regional Governments

When making public investment decisions, the central government considers the regional government's investment behavior, and vice versa; thus, the model should entail the complementary or substitutionary relationship of investment by the two governments. To this end, we used a transformation that considers the investment of the central government as a dependent variable of regional government investment, and the investment of regional government as a dependent variable of central government investment. First, letting the amount of public infrastructure investment in region i at time t be I_{it} and the depreciation rate of public infrastructure stock be δ, the accumulation equation of public infrastructure stock is $C_{it} = I_{it} + (1 - \delta) C_{it-1}$. When $I_{it} / C_{it} - \delta$ is sufficiently small, we can obtain

$$\Delta \ln C_{it} = \ln(1 + I_{it} / C_{it} - \delta) \simeq I_{it} / C_{it} - \delta .$$

Here, public infrastructure investment I_{it} is divided into central and regional government investments, and denoted as I^C_{it} and I^R_{it}, respectively. The fiscal resources of I^C_{it} are basically provided at the national expense and include the investment amount of state-owned enterprises (i.e., Korea Expressway Corporation for expressways and Korea Railroad Authority for high-speed rails). I^R_{it} instead represents the input of regional expenses and the investment amount of regional public enterprises. In the case of facilities that share financial resources by national treasury and regional expenses, each contribution is counted separately in I^C_{it} and I^R_{it}.

Following the setting of Castells and Solé-Ollé (2005), the possibility of substitution between I^C_{it} and I^R_{it} is expressed as parameter θ. Thus, we can determine whether the relationship between the central and regional government's public infrastructure investment is complementary or substitutionary in the situation of the ROK with this parameter estimate.

We assumed that from the point of view of the central government at time t, the value of I_{it}^R is unknown, such that the investment ratio of the regional government to the public capital stock in each region is expected to be the same as the previous time period. That is, we have

$$\Delta \ln C_{it} \simeq I_{it}^C / C_{it-1} + \theta(I_{it-1}^R / C_{it-2}),$$

and for $\Delta \ln C_{it-1}$, because the actual regional investment I_{it-1}^R and the level of the public capital stock of the previous time period C_{it-2} can be known, we can obtain

$$\Delta \ln C_{it-1} \simeq I_{it-1}^C / C_{it-2} + \theta(I_{it-1}^R / C_{it-2}),$$

as in Castells and Solé-Ollé (2005, p. 1175). Substituting these in Equation (11) and rearranging it, we find

$$I_{it}^C / C_{it-1} = (1-\rho)(I_{it-1}^C / C_{it-2}) - \rho\theta(I_{it-1}^R / C_{it-2}) + \rho\phi\Delta \ln Y_{it-1} + \\ \rho(1-\phi)\Delta \ln N_{it-1} + \rho\Delta \ln S_{it-1}^X + \rho\Delta \ln E_{it-1}^C + \rho\Delta \ln \Psi_{it}^e + f_t + \Delta\varepsilon_{it}. \quad (14)$$

In Equation (14), the sum of coefficients of I_{it-1}^C / C_{it-2}, $\Delta \ln Y_{it-1}$, and $\Delta \ln N_{it-1}$ is $(1-\rho) + \rho\phi + \rho(1-\phi) = 1$ (Castells and Solé-Ollé, 2005, p. 1184). Therefore, whether this constraint is established as a result of estimation should be tested to confirm the model fit. For this, if we use $\Delta \ln(Y_{it-1} / N_{it-1})$ instead of $\Delta \ln Y_{it-1}$ in Equation (13), the coefficients of $\Delta \ln(Y_{it-1} / N_{it-1})$ and $\Delta \ln N_{it-1}$ are obtained as $\rho\phi$ and ρ, respectively. Therefore, the model used for estimation can be expressed as

$$I_{it}^C / C_{it-1} = (1-\rho)(I_{it-1}^C / C_{it-2}) - \rho\theta(I_{it-1}^R / C_{it-2}) + \rho\phi\Delta \ln(Y_{it-1} / N_{it-1}) + \\ \rho\Delta \ln N_{it-1} + \rho\Delta \ln S_{it-1}^X + \rho\Delta \ln E_{it-1}^C + \rho\Delta \ln \Psi_{it}^e + f_t + \Delta\varepsilon_{it}, \quad (15)$$

where $\Delta \ln \Psi_{it}^e$ is to be substituted by Equation (12). Accordingly, the verification of the realistic fit of the model can be simplified to testing whether the sum of the coefficients of I_{it-1}^C / C_{it-2} and $\Delta \ln N_{it-1}$ is 1.

3.5. Estimation Strategies

As discussed above, to estimate Equation (15), the points to be noted when estimating the general dynamic panel model should be considered. We assumed that the error term ε_{it} has zero mean, a constant variance, and no serial correlation. Although the error term ε_{it} has no serial correlation, the first difference $\Delta\varepsilon_{it}$ has a negative autocorrelation. Therefore, in the dynamic panel model of Equation (15), an endogeneity problem occurs in which the lagged dependent variable I_{it-1}^{C} / C_{it-2} and $\Delta\varepsilon_{it}$ are correlated. In this case, generally, a typical OLS estimator is not an unbiased estimator unless the number of time periods in data is extremely large (Arellano and Bond, 1991). To solve this problem, we estimated the model using the generalized method of moments (GMM), more specifically, the difference GMM proposed by Arellano and Bond (1991).

Here, similar to Castells and Solé-Ollé (2005), the levels of the past infrastructure stocks, $\ln C_{it-2}$ to $\ln C_{it-8}$, were used as instruments for I_{it-1}^{C} / C_{it-2}, because generally, using the past infrastructure stock levels as instruments has better estimation results than using their first difference value (Arellano, 1989). However, a larger number of past infrastructure stocks may be used as instruments because the data correspond to a sufficiently long period (spanning more than 50 quarters). The range of instruments was restricted from $\ln C_{it-2}$ to $\ln C_{it-8}$ because using too many instruments degrades the performance of GMM estimators, especially when the number of samples is small (Kiviet, 1995). In addition, we used I_{it-2}^{C} / C_{it-3} as a general GMM-type instrument, and the first difference values of economic, political, and fiscal variables as standard instruments. Lastly, testing whether there no serial correlation existed in the error term ε_{it} was necessary because this is required for the GMM estimator to be a consistent estimator.

Potential weaknesses of a difference GMM include that (a) the lagged levels are poor (weak) instruments for first differenced variables, especially if the endogenous variable is persistent or close to a random walk (Blundell and Bond, 1998) and (b) the first difference transformation magnifies gaps in unbalanced panels. Although the latter weakness is not an issue in this study because we used a balanced panel, the former has to be confirmed by testing the serial correlations. To circumvent the above issue, one may rely alternatively on a system GMM, in which instruments include lagged levels, lagged differences, or both (Arellano and Bover, 1995 and Blundell and Bond, 1998). However, we have to make additional initial conditional assumption to apply a system GMM. A sufficient but unnecessary condition for this to hold is the joint mean stationarity of the dependent and independent variables, which is not clearly justifiable for this study (Blundell, Bond, and Windmeijer, 2001).

IV. Variables and Data

As previously explained, the variables were largely divided into three categories: economic, political, and fiscal. In terms of availability, the data were constructed quarterly from 2001 to 2014 at the provincial and metropolitan city levels.

4.1. Economic Variables

The net capital stock of public infrastructure by region was obtained from the original data in Lee (2018). The investment amount by region was calculated by the central government (I_{it}^{C}) and the regional government (I_{it}^{R}), according to the orderers (central and regional governments) in the infrastructure sector by region in the "Construction Industry Survey" of Statistics Korea, which is a "designated statistics" used to calculate the GDP, gross regional domestic product (GRDP), and input–output table, to name a few. Alternatively, one can consider the amount of investment in the "Local Finance Yearbook" published by the Ministry of the Interior and Safety (MOIS). However, using it is impossible because it has only reported the regional governments' investment by the infrastructure sector without the central government's sectoral division of investment by region since 2012. The capital stock and investment by region are measured in billion Korean Won (KRW), and both are in real values at chained 2010 year prices.

The population growth rate by region ($\Delta \ln N_{it-1}$) was based on the "Statistics of Registered Population" data from the MOIS. As data have been released monthly since 2008, quarterly rates were calculated during this period. As a result of F-test by region and quarter using 2008 data, proving a significant statistical difference between quarters was impossible. Therefore, the annual growth rate from 2001 to 2007 was used to calculate the quarterly growth rate as a geometric mean.

The rate of increase in regional production (GRDP) per capita $\Delta \ln(Y_{it} / N_{it})$ was calculated by applying the GDP deflator to the total GRDP per administrative area provided by the Statistics Korea to obtain the real per capita GRDP in billion KRW. Given that only annual data are available, a quarterly geometric mean was applied to calculate the quarterly increase rate. Alternatively, one may consider applying the available quarterly growth rate of the real GDP with adjustment to the ratio of the annual growth of the GRDP to that of the GDP to construct the quarterly GRDP series. The quarterly movement of regional products may resemble the pattern of the entire country's products (for large and representative regional economies, in particular). However, we did not adopt this approach for two reasons. First, other than representative regions, the quarterly synchronization of GRPD and GDP may be unnecessary. Second, there exist several cases where the GRDP has fallen although the GDP has grown on an annual basis, which makes applying this approach impossible.

Given that no vehicle stock level information is available, the proportion of traffic volume compared with the production volume S_{it}^{X} was replaced by assuming $S_{it}^{X} = (CommVeh_{it} / Y_{it})^{\gamma}$, where $CommVeh_{it}$ is the number of commercial vehicles in region i at time t. The proportion of commercial automobiles compared with production was based on the data from the Ministry of Land, Infrastructure, and Transport (MOLIT)'s "Total Registered Motor Vehicles."

Instead of assuming a constant elasticity as is frequently done in similar empirical studies, for the elasticity of transportation services of public infrastructure stock E_{it}^{C}, we assumed that the effect of raising public infrastructure stock increases with the level of use. To implement this in estimation, we substituted variables that indicate an increase in the number of users in place of $\Delta \ln E_{it}^{C}$ (for more details, see Castells and Solé-Ollé, 2005, p. 1181.) For roads, we replaced $\Delta \ln E_{it}^{C}$ with the quarterly increase in road traffic $\Delta \ln Road_{it}$. For railroads and airports, we considered quarterly change in rail passengers $\Delta \ln Rail_{it}$ and in airport passengers $\Delta \ln AirPass_{it}$ and cargo traffic $\Delta \ln AirFreight_{it}$. In the case of ports, the quarterly volume increase $\Delta \ln Port_{it}$ was included.

Finding unified data to determine the use of road service is difficult. Therefore, for provinces that are expected to have high interregional transportation, we used the traffic volumes of the highways, national roads, state-supported local roads, and local roads in the "Statistical Yearbook of Road Traffic Volume" of the MOLIT. In the case of metropolitan cities, regional statistics were used because we expected that intraregional traffic would dominate rather than interregional transportation.

Quarterly data were corrected using the quarterly average of the monthly correction index in the region provided by the "Statistical Yearbook of Road Traffic Volume." The monthly correction index for national roads has been continuously provided since 2000. However, given that no relevant information on local and state-supported local roads is available, the values of the national roads for each region were used instead. In the case of highways, the monthly correction index has been provided since 2014, and this value was used as a representative value. To build quarterly data for metropolitan cities, the average of traffic volumes from the "Statistical Yearbook of Road Traffic Volume" in relation to the survey points on the highways located in a metropolitan city was used as the representative value for the city (e.g., for Seoul, the average traffic volumes at the city's survey points located on Gyeongbu, Seoul-Yangyang, and Seoul Ring Expressways.) In summing up the traffic volumes of each type of road in a region, weights were given by the proportion of each type of road by region published in the MOLIT's "Road Statistics."

To build railway passenger data, the number of annual railroad passengers was obtained by summarizing the number of passengers traveling both ways at each station in the "Flow Table of Passenger Between Stations" of the "Statistical Yearbook of Railroad," and the number of passengers of each regional subway company. Given that quarterly data for this traffic volume are unavailable, the growth rate was calculated using the geometric mean between quarters. For the use of airports, quarterly data were constructed using monthly passengers (persons) and cargo (tons) from the "Aviation Statistics" of the Korea Airports Corporation. The port container throughput was calculated using the monthly data for each port of the "Cargo Handling Statistics" based on the reported information of port users.

4.2. Political Variables

Depending on the political situation in the ROK, which has a centralized nature, the analysis appropriately reflects the results of the general election for the National Assembly. Such results can have a more substantial effect on the budgeting of the central government than the results of the election of the head of the regional government. However, this process requires the aggregation of the electoral districts into metropolitan and provincial units to consider the differences between the electoral districts of the general elections and the metropolitan cities and provinces as the regional units of this study. In addition, reflecting the electoral system for the National Assembly of the ROK, which adopts a single-member constituency, and the region-specific political supporting behavior of voters would be desirable. For example, a long-lasting East–West divide in political preference is well-known in the ROK. We considered the two incentives of political influence introduced previously, namely, electoral productivity and partisanship.

In terms of electoral productivity, we considered the turnout t_{ik} and the voting margin between ruling party candidates and other candidates m_{ik}. Here, t_{ik} is defined as the ratio of the number of votes to the population by region. From the perspective of the ruling party candidate, m_{ik} is defined as the reciprocal of the average of the difference in votes with runners-up by region when the ruling candidate is elected. Otherwise, it takes the reciprocal of the regional average of the difference in votes between the ruling party candidate and the winner.

From a partisanship perspective, we considered the ratio of the ruling party's member of the National Assembly by region e_{ik} and the ruling party's electoral turnover by region r_{ik}, which is defined as the proportion of the districts in which the current and former lawmakers are ruling parties in the region. Here, reelection variables of the ruling party were considered to reflect the characteristics of the regional separation as a result of past elections in the ROK. In other words, if only the result of the last election is included, ruling out the effect of a temporary political issue on the election result is impossible. Hence, we considered the existence of the so-called political turf or "backyard" region, in which a specific political party is favored, regardless of the candidates' characteristics.

The results of the by-elections or special elections were reflected in a limited manner. For example, they were not included in the voter turnout because the gap between regular and special elections was extremely large, which could lead to a distortion. This condition applies equally to the difference in votes between ruling party candidates and other candidates. However, including the results of the special elections was judged reasonable, in that the proportion of the National

Assemblymen by region and the reelection variables of the ruling party had little distortion between regions and could thus reflect the latest information on regional political support.

Moreover, some regions do not have a National Assemblyman of the ruling party present in the current Assembly or no one from the ruling party is reelected consecutively. For logarithmic transformations, e_{ik} and r_{ik} must be converted by adding 1 to each to prevent divergence. Accordingly, the functional form of the political variables is defined as

$$\ln \Psi_k = \ln(t_{ik} \times m_{ik} \times (e_{ik}+1) \times (r_{ik}+1)) = \ln(t_{ik} m_{ik}) + \ln((e_{ik}+1)(r_{ik}+1)). \quad (16)$$

The main interest here is how political influence works in allocating public investment from the perspective of electoral productivity ($\ln(t_{ik} m_{ik})$) and partisanship ($\ln((e_{ik}+1)(r_{ik}+1))$).

4.3. Fiscal Variables

To reflect the fiscal space of each regional government, such as budget constraints, we included regional fiscal variables. In so doing, in view of the circumstances in the ROK, fiscal variables were selected as the growth rates of regional finance income $\Delta \ln Rev_{it}$, regional grants $\Delta \ln Grant_{it}$, regional tax revenue $\Delta \ln Tax_{it}$, regional debt $\Delta \ln Debt_{it}$, and fiscal independence $\Delta \ln Indep_{it}$.

We used the data that appeared in the financial analysis of tax revenues by regional government in the "Local Finance Yearbook" of the MOIS. The items included here were "local tax," "extra income," "local grant tax, grant, compensation, subsidy, redistribution, etc.," and "local bonds and deposit recovery." In addition, the fiscal independence of metropolitan cities and provinces was calculated from the original budget in the same yearbook, and its growth rate was obtained using the geometric mean between quarters.

Table 1 summarizes the variables used, their basic statistics, and data sources.

V. Estimation Results and Discussions

We conducted estimations for the entire transportation infrastructure covering roads, railroads, and ports, as well as for roads only. Road infrastructure was targeted separately because it is the representative transportation infrastructure that occupies a dominant position. The expansion of the ROK's transportation infrastructure has been centered on roads, which has resulted in a considerably higher concentration of investment and level of stock than other type of

[Table 1] Definitions, Basic Statistics, and Data Sources of Variables

Variable		Definition	Mean	Std. Dev.	Sources
Economic					
I_{it}^{C} / C_{it-1}	Transportation infrastructure	Transportation infrastructure investment by the central government compared with the capital stock of the previous period	0.01104	0.006785	• Quarterly capital stock by region (Bank of Korea) • National Wealth Survey 1997 (Statistics Korea) • Construction Industry Survey (Statistics Korea)
	Road		0.008848	0.006506	
I_{it}^{R} / C_{it-1}	Transportation infrastructure	Transportation infrastructure investment by the regional government compared with the capital stock of the previous period	0.006024	0.003324	
	Road		0.006258	0.003024	
$\Delta \ln(Y_{it-1} / N_{it-1})$		Growth rate of per capita GRDP	0.01427	0.008400	• Regional income (Statistics Korea) • Statistics of Registered Population (MOIS)
$\Delta \ln N_{it-1}$		Population growth rate	0.0008539	0.002519	• Statistics of Registered Population (MOIS)
$\Delta \ln(CommVeh_{it} / Y_{it})$		Growth rate of the proportion of commercial vehicles compared with the GRDP	0.002546	0.01626	• Regional income (Statistics Korea) • Total Registered Motor Vehicles (MOLIT)
$\Delta \ln Road_{it-1}$		Growth rate of road traffic volume	0.002573	0.08632	• Statistical Yearbook of Road Traffic Volume (MOLIT) • Road Statistics (MOLIT) • Regional statistics (each regional government)
$\Delta \ln Rail_{it-1}$		Growth rate of railroad passengers	0.01173	0.04984	• Statistical Yearbook of Railroad (Korail) • Number of passengers (each regional subway company)
$\Delta \ln AirPass_{it-1}$		Growth rate of airport passengers	−0.0003409	0.1728	• Aviation Statistics (Korea Airports Corporation)
$\Delta \ln AirFreight_{it-1}$		Growth rate of airport cargo volume	−0.004020	0.1986	• Cargo Handling Statistics (PORT-MIS)
$\Delta \ln Port_{it-1}$		Growth rate of container throughput	0.005395	0.09332	

[Table 1] Definitions, Basic Statistics, and Data Sources of Variables (continued)

Variable	Definition	Mean	Std. Dev.	Source
Political				
t_{ik}	Ratio of votes to population	0.5545	0.06486	• Electoral results (National Election Commission)
m_{ik}	Reciprocal of the vote difference with the runner-up if the ruling party's candidate is elected, and reciprocal of the difference with the winner otherwise	0.002051	0.01304	
e_{ik}	Proportion of the ruling party's members of the National Assembly	0.4546	0.3626	
r_{ik}	Proportion of incumbent and former members of the National Assembly belonging to the ruling party	0.2094	0.2639	
Fiscal				
$\Delta \ln Rev_{it-1}$	Growth rate of regional finance income	0.01803	0.01890	• Local Finance Yearbook (MOIS) • Statistical Yearbook of Local Tax (MOIS)
$\Delta \ln Grant_{it-1}$	Growth rate of regional grants	0.02315	0.03049	
$\Delta \ln Tax_{it-1}$	Growth rate of regional tax revenue	0.02058	0.01989	
$\Delta \ln Debt_{it-1}$	Growth rate of regional debt	0.005326	0.05709	
$\Delta \ln Indep_{it-1}$	Growth rate of fiscal independence	−0.004928	0.01435	

infrastructure. Although Lee (2018) found that the proportion of road investments relative to railroads in the country is close to the OECD average, the share of roads in the transportation infrastructure in terms of the net capital stock was around three quarters throughout the duration of this study. By contrast, no separate estimation was made for the railroad and port sectors due to the fact that the relative weight of both sectors is small and that they are greatly influenced by specific individual projects, such as high-speed rail and large-scale port development projects.

To check the effects of the variables of interest closely and confirm the robustness of the model, we estimated three model specifications: Model I, which includes only economic variables; Model II, which includes economic and political variables; and Model III, which fully considers all variables of interest. The estimation results of each model are reported in Table 2. The results show a slight difference in the size and statistical significance of the parameter estimates but reveal a similar trend. Therefore, hereinafter, the estimation results will be discussed centering on the full model, namely, Model III.

In the case of the entire transportation infrastructure, the parameter estimates for the time-varying variables of the investment ratio of the central and regional government compared with the capital stock of the transportation infrastructure were all statistically significant. The coefficient estimates of I_{it}^{C}/C_{it-1} and $\Delta \ln N_{it-1}$ are greater than 1 and have a negative value. Consequently, this infers a negative value for $\hat{\rho}$, and the parameter estimates below must be interpreted by changing the sign to reflect this fact.

Statistical significance was confirmed in the estimation results of parameters representing the trade-off between equity and efficiency. The Wald test result to confirm the model's fit to the data also shows that we cannot reject the sum of the coefficient estimates of I_{it}^{C}/C_{it-1} and $\Delta \ln N_{it-1}$ equals to 1, suggesting that the model adequately describes the reality. In addition, as a result of the serial correlation test on the first difference value of the error term $\Delta\varepsilon_{it}$, findings confirmed that there exists a first-order serial correlation but no second-order serial correlation, and no serial correlation thus exists in the error term ε_{it}, which validates the use of a difference GMM. In particular, not rejecting the null hypothesis of no first-order serial correlation indicates that ε_{it} follows a near-unit root process such as random walk, which causes a weak instrument problem when using a difference GMM.

Accurate interpretations of the estimation results are possible after rearranging the parameters by proper forms of variables, but some inferences can be made by looking at the original estimation results in Table 2. First, after examining whether the resource allocation has been made in accordance with the demand for transportation infrastructure, we can conjecture that investment tends to be concentrated in regions with a large increase in road use. By contrast, different from

[Table 2] Estimation Results

Variable	Model I: Economic		Model II: Economic and Political		Model III: Full	
	Transportation infrastructure	Road	Transportation infrastructure	Road	Transportation infrastructure	Road
Lagged central and regional governments' investments						
I^{C}_{it-1} / C_{it-2}	1.011*** (30.09)	0.9632*** (28.44)	1.027*** (29.65)	0.9945*** (27.69)	1.037*** (29.89)	0.9962*** (27.80)
I^{R}_{it-1} / C_{it-2}	−0.3299*** (−4.54)	−0.2597*** (−3.81)	−0.3627*** (−4.86)	−0.3173*** (−4.46)	−0.2916*** (−3.68)	−0.2814*** (−3.71)
Equity–efficiency trade-off						
$\Delta\ln(Y_{it-1} / N_{it-1})$	0.01580* (1.92)	0.02276*** (2.78)	0.01028 (1.20)	0.01943** (2.26)	0.01927** (2.11)	0.02490*** (2.71)
$\Delta\ln N_{it-1}$	−0.1117*** (−3.40)	−0.1290*** (−4.02)	−0.1204*** (−3.62)	−0.1332*** (−4.06)	−0.09367*** (−2.76)	−0.1127*** (−3.37)
Wald ($I^{C}_{it-1} / C_{it-2} + \Delta\ln N_{it-1} = 1$)	4.24 [0.0395]	11.49 [0.001]	3.55 [0.0597]	7.47 [0.006]	1.27 [0.259]	5.26 [0.022]
Demand of public infrastructure						
$\Delta\ln(CommVeh_{it-1} / Y_{it-1})$	0.03418*** (4.39)	0.04108*** (5.24)	0.02505*** (2.99)	0.03386*** (4.02)	0.02387*** (2.62)	0.02969*** (3.27)
$\Delta\ln Road_{it-1}$	−0.001626*** (−3.24)	−0.0007058 (−1.48)	−0.001608*** (−3.17)	−0.0006580 (−1.35)	−0.001550*** (−3.09)	−0.0006268 (−1.30)
$\Delta\ln Rail_{it-1}$	−0.001832 (−1.27)	—	−0.001640 (−1.13)	—	−0.001435 (−0.95)	—
$\Delta\ln AirPass_{it-1}$	−0.0003736 (−0.92)	—	−0.0003439 (−0.84)	—	−0.0004854 (−1.19)	—
$\Delta\ln AirFreight_{it-1}$	0.0003509 (1.02)	—	0.0003525 (1.01)	—	0.0002325 (0.67)	—
$\Delta\ln Port_{it-1}$	0.0003170 (0.68)	—	0.0002654 (0.56)	—	0.0001710 (0.36)	—

[Table 2] Estimation Results (continued)

Variable	Model I: Economic		Model II: Economic and Political		Model III: Full	
	Transportation infrastructure	Road	Transportation infrastructure	Road	Transportation infrastructure	Road
Political influence I: Electoral productivity						
$d_{3t}\Delta\ln(t_{ik}m_{ik})$	—	—	−0.0002550** (−2.13)	−0.0002952** (−2.48)	−0.0002702** (−2.23)	−0.0003393*** (−2.83)
$d_{3t}\ln(t_{ik-1}m_{ik-1})$	—	—	−0.0002791** (−2.31)	−0.0003491*** (−2.92)	−0.0003202*** (−2.62)	−0.0004214*** (−3.51)
$(1-d_{3t})\ln(t_{ik}m_{ik})$	—	—	−0.0002672** (−2.25)	−0.0003168*** (−2.70)	−0.0003067** (−2.55)	−0.0003888*** (−3.29)
Political influence II: Partisanship						
$d_{3t}\Delta\ln((e_{ik}+1)(r_{ik}+1))$	—	—	−0.0006728 (−1.36)	−0.0003157 (−0.66)	−0.0005776 (−1.17)	−0.0002093 (−0.44)
$d_{3t}\ln((e_{ik-1}+1)(r_{ik-1}+1))$	—	—	−0.0005205 (−0.90)	−0.0002420 (−0.44)	−0.0005469 (−0.96)	−0.0001637 (−0.30)
$(1-d_{3t})\ln((e_{ik}+1)(r_{ik}+1))$	—	—	−0.0005479* (−1.66)	−0.0002331 (−0.79)	−0.0006238* (−1.88)	−0.0002636 (−0.89)
Fiscal conditions						
$\Delta\ln Rev_{it-1}$					0.003735 (0.82)	0.008659* (1.94)
$\Delta\ln Grant_{it-1}$					0.008655*** (3.00)	0.005429* (1.94)
$\Delta\ln Tax_{it-1}$					0.003134 (0.75)	0.007596* (1.85)
$\Delta\ln Debt_{it-1}$					−0.001129 (−1.02)	0.0004920 (0.46)
$\Delta\ln Indep_{it-1}$					−0.01452*** (−3.06)	−0.01090** (−2.41)

[Table 2] Estimation Results (continued)

Variable	Model I: Economic		Model II: Economic and Political		Model III: Full	
	Transportation infrastructure	Road	Transportation infrastructure	Road	Transportation infrastructure	Road
Time effect						
t	−0.0000362*** (−4.01)	−0.0000369*** (−4.10)	−0.0000379*** (−4.01)	−0.0000397*** (−4.22)	−0.0000293*** (−2.68)	−0.0000348*** (−3.28)
Number of observations	16×47=752	16×47=752	16×47=752	16×47=752	16×47=752	16×47=752
χ^2	5400.38 [0.000]	4672.37 [0.000]	5337.02 [0.000]	4559.03 [0.000]	5516.20 [0.000]	4722.88 [0.000]
LM (first-order serial correlation)	−9.788 [0.000]	−10.65 [0.000]	−9.728 [0.000]	−10.67 [0.000]	−9.766 [0.000]	−10.74 [0.000]
LM (second-order serial correlation)	−0.4369 [0.662]	−0.03212 [0.974]	−0.4748 [0.635]	−0.1283 [0.8979]	−0.5709 [0.568]	−0.2083 [0.835]
Sagan	126.36 [0.000]	181.89 [0.000]	116.21 [0.000]	165.98 [0.000]	105.13 [0.001]	160.77 [0.000]

Note: Numbers in parentheses and brackets refer to z and p values, respectively. Asterisks indicate statistical significance: *, $p < 0.1$; **, $p < 0.05$; ***, $p < 0.01$.

what was expected, there does not seem to be a large investment in a region where the proportion of commercial vehicles to output increases rapidly. Second, by examining the political influence on the allocation of public investment in transportation infrastructure by region, the incentive according to the electoral productivity acts more strongly than the incentive caused by partisanship. Third, from the trend of investment according to regional financial conditions, we could infer that the higher the regional grants and/or the greater the increase in fiscal independence is, the higher the investment will be.

Now, from the estimation results of Model III, Table 3 summarizes the key parameter estimates representing the net partial effects of the variables, removing the other parameters in the coefficient if there are any. First, all the structural parameters having economic meanings in the model were statistically significant. As discussed above, the capital stock adjustment parameter $\hat{\rho}$ was estimated as a negative value. As described in Equation (9), it represents the sluggishness in the capital stock adjustment of the central government to the long-term optimal level of capital stock due to the difficulty to immediately reflect the change in characteristics of the region to the allocation of investment. The negative $\hat{\rho}$ indicates that the observed level of capital stock was higher than the optimal level. According to the model set by this study, this can be interpreted as a result suggesting that there was an overinvestment in transportation infrastructure during the estimation period. Although the direct comparison of two specifications in Model III is limited, comparing $\hat{\rho}$ may suggest that the tendency for overinvestment in roads was relatively higher than for the entire transportation infrastructure. This result may be due to the establishment of a policy direction in which the transportation infrastructure investment of the ROK is focused on roads, as mentioned earlier. However, as indicated above for the setting of regional production function, attention should be paid to this interpretation in that interactions between regions are not explicitly modeled in consideration of the estimation burden, data limitations, and main concerns of this study. In the future, the appropriateness of the investment scale should be further investigated through more in-depth studies.

The negative estimate of parameter $\hat{\theta}$ indicates the substitutability between investments by the central and regional governments and is logical and legitimate result from the infrastructure funding scheme in the ROK. This result is in line with the results estimated by Castells and Solé-Ollé (2005) using Spanish data, whose model is largely borrowed for this study, rather than Aronsson et al. (2000) using Swedish data.

The parameter representing the trade-off between equity and efficiency ϕ, the main parameter of interest in this study, was estimated as a negative number. As shown in Equation (4), in this case, equity is more emphasized than when the SWF is Cobb–Douglas ($\phi = 0$). This result is consistent with Ahn and Kim's (2006) study, which was introduced above, determining that the regional allocation of

[Table 3] Parameter Estimates of Key Variables

Variable	Transportation infrastructure	Road
Structural parameter		
Sluggishness (ρ)	−0.01927*** (−2.76)	−0.1127*** (−3.37)
Substitutability (θ)	−3.113** (−2.20)	−2.496** (−2.45)
Equity–efficiency trade-off (ϕ)	−0.2057* (−1.79)	−0.2208** (−2.25)
Demand of public infrastructure		
$\Delta\ln(CommVeh_{it-1} / Y_{it-1})$	−0.2549* (−1.95)	−0.2633** (−2.39)
$\Delta\ln Road_{it-1}$	0.01655** (2.16)	0.005559 (1.25)
$\Delta\ln Rail_{it-1}$	−0.01532 (−0.88)	—
$\Delta\ln AirPass_{it-1}$	0.005182 (1.08)	—
$\Delta\ln AirFreight_{it-1}$	−0.002482 (−0.64)	—
$\Delta\ln Port_{it-1}$	−0.001825 (−0.37)	—
Political influence I: Electoral productivity		
$d_{3t}\Delta\ln(t_{ik}m_{ik})$	0.002885* (1.72)	0.003010** (2.13)
$d_{3t}\ln(t_{ik-1}m_{ik-1})$	0.003418* (1.91)	0.003738** (2.42)
$(1-d_{3t})\ln(t_{ik}m_{ik})$	0.003275* (1.87)	0.003449** (2.35)
Political influence II: Partisanship		
$d_{3t}\Delta\ln((e_{ik}+1)(r_{ik}+1))$	0.006167 (1.10)	0.001857 (0.44)
$d_{3t}\ln((e_{ik-1}+1)(r_{ik-1}+1))$	0.005839 (0.92)	0.001452 (0.30)
$(1-d_{3t})\ln((e_{ik}+1)(r_{ik}+1))$	0.006660 (1.61)	0.002339 (0.89)
Fiscal conditions		
$\Delta\ln Rev_{it-1}$	−0.03988 (−0.76)	−0.07681 (−1.59)
$\Delta\ln Grant_{it-1}$	−0.09240** (−2.01)	−0.04816* (−1.67)
$\Delta\ln Tax_{it-1}$	−0.03346 (−0.75)	−0.06737* (−1.71)
$\Delta\ln Debt_{it-1}$	0.01206 (0.93)	−0.004364 (−0.46)
$\Delta\ln Indep_{it-1}$	0.1550* (1.94)	0.09672* (1.86)

Note: Numbers in parentheses refer to z values. Asterisks indicate statistical significance: *, $p < 0.1$; **, $p < 0.05$; ***, $p < 0.01$.

transportation infrastructure investment in the ROK was located between "allocation for equity" and "allocation for equality." This result also agrees with Lee and Choe (2010) who showed that public capital was not efficiently allocated in the ROK based on the marginal productivity of capital, but that the country sought spatial equity based on regional production. Although limited, the consideration of equity was reflected to a relatively higher extent in the allocation of investment by region in the case of roads rather than the entire transportation infrastructure. This deduction is caused by the number of railroad and port projects being smaller, whereas the scale of their individual projects are often larger compared with roads, and there exists relatively less room for equity consideration.

When checking whether the allocation was made according to the demand for transportation infrastructure, investment was confirmed to be concentrated in regions with a large increase in road use in terms of the entire transportation infrastructure as previously conjectured. However, for the entire transportation infrastructure and roads, the result of not investing heavily in the region where the proportion of commercial vehicles is rapidly increasing compared with output is contrary to expectations. In this regard, if the data are available in the future, complementary research will be necessary, for example by subdividing the types of commercial vehicle or using the proportion of freight cargoes compared with the amount of production.

When the entire transportation infrastructure was considered again, demand for railroads, airports, and ports does not appear to have a significant effect on investment allocation decisions. This result may be due to the lack of consideration in relation to these types of facility when allocating transportation infrastructure investment by region. However, it may also be due to the fact that their proportion in the total transportation infrastructure is relatively small as a result of the road-oriented investment in the ROK.

When examining the political influence on the allocation of public investment by region, only incentives according to election productivity have a statistically significant effect on transportation infrastructures overall and roads. In other words, the more the number of voters compared with population and the more competitive the region in the previous election was, the more the government would tend to invest during the period of 2001–2014. However, the null hypotheses of $H_0 : \beta_s - \beta_{s+1} = \beta$ for $s = 0,1,2$ are rejected in both cases, which suggests that more sophisticated modeling is necessary. Further analysis of this result will be left as a future research project.

In both specifications of Model III, the investment trend according to regional financial conditions was confirmed to be higher as the growth in regional grants and financial independence is reduced and increased, respectively. This result provides a clue to speculate that investment in regions with improving financial conditions has increased to some extent. However, given that statistical significance was confirmed for other financial variables, the result must be interpreted in a limited manner. Nevertheless, this constitutes implicitly provided empirical evidence for the logical analogies by Cho et al. (2012, p. 53). They pointed out the problem of national fiscal support standards being uniformly applied to the regions instead of reflecting the geographical characteristics of infrastructure projects or the financial situation of the regional government in the sharing of infrastructure investment costs between the central and regional governments in the ROK. They also argued that:

The state-subsidized infrastructure project has a fixed support rate or amount

> *by type, which does not reflect the characteristics of the region where the project is being implemented. With the fixed support rate, the larger the scale of the project, the more it can receive national subsidies. Conversely, regional governments also share the cost in proportion to receiving government support, making it difficult to apply for large-scale projects where financial conditions are unsatisfactory. As a result of applying the uniform national fiscal allocation standard, there is a phenomenon in which national treasury support is concentrated on regional governments with high fiscal independence.* (Cho et al., 2012, pp. 53–54).

In light of the fact that changes in road traffic did not have a significant effect on investment and that investment was expanded in regions with shrinking regional tax revenues from the estimation results for the roads, we could infer that the equity is more concerned when investing in roads compared with the overall transportation infrastructure. This result fortifies the previous interpretation of the parameter estimate $\hat{\phi}$ representing the trade-off between equity and efficiency.

Thus far, we have discussed the estimation results based on the economic model using the quarterly data. However, one may argue that the budgeting in the ROK is on an annual basis in reality. Using the quarterly data was mainly due to the insufficiency of data in terms of length and availability. Accordingly, the use of annual data is inevitably excluded from the empirical perspective.

The actual investment decisions of governments on infrastructure are made with respect to longer term than a year because most large-scale infrastructure, such as roads and railroads, requires several years to finish construction. The investment plan for each year during the construction period is mapped out before the construction begins. On this basis, using the annual data may also be different from the reality to some extent.

Nevertheless, in view of the annual budgeting cycle in the ROK, we may conceive a plot in which the central government makes annual budgetary decisions. In so doing, the central government determines the quarterly allocation of resources year by year, which still allows us to use the quarterly data. In making quarterly investment decision on an annual basis, the central government relies on the information revealed in previous year's corresponding quarter. Then, the laggings $t-1$ and $t-2$ in the explanatory variables become $t-4$ and $t-5$, respectively. However, the performance of estimation in this setup was considerably poorer than the results presented in this study, which implies that the actual decision making of the central government may not resemble this situation.

Moreover, the actual budgetary outlays on infrastructure projects are generally made quarterly, which creates a room for the central government to adjust the quarterly investment amount although the entire year's budget was set before. In part, this fact advocates the central government's quarterly investment decision assumed in this study. Nevertheless, the current empirical results were obtained without flawless reflections of the longer-term perspectives of the central government's decision beyond the quarterly period, which is a limitation of this study mainly due to lack of data.

Finally, we conducted several further verification studies to determine whether the consideration of equity–efficiency in the regional allocation of transportation infrastructure investment changed over time, but could not confirm statistically significant changes during the period of the given data. First, the model was estimated by substituting ϕ for $\phi_t = \phi_0 + \phi_1 t$ to allow the parameter representing the trade-off between equity and efficiency to change over time; however, $\hat{\phi}_1$ was not statistically significantly different from zero. Second, the same analysis of this study was performed by dividing the data into two periods. Considering the timing of the data and the timing of regime change made in the first quarter of 2008, the data were divided into "Period 1: Q2 2001 to Q4 2007" and "Period 2: Q1 2008 to Q4 2014." In other words, Periods 1 and 2 include the 27 quarters of the Kim Dae-jung and Roh Moo-hyun administrations and the 28 quarters of the Lee Myung-bak and Park Geun-hye administrations, respectively. In this case, the estimation results were extremely poor, mainly because the data used for the estimation of each model were reduced by half. Third, the model was estimated by allowing ϕ to have different values between two time periods distinguished based on the above criterion, but the statistical significance could not be confirmed in most cases.

VI. Concluding Remarks

In this study, we used a structural model to determine which aspects of efficiency and equity criteria were advocated in allocating investment in transportation infrastructure by region in the ROK during the period of 2001–2014. The results of the setting and estimating of the structural model are discussed as follows.

First, the estimation result suggests that the country's regional allocation of investment in transportation infrastructure has emphasized equity rather than efficiency to promote BRD. The SWF was estimated in such a way to consider equity more than the form of the Cobb–Douglas function, in which the allocation is made in proportion to the size of the regional labor input. This result is in line with the findings by Ahn and Kim (2006) and Lee and Choe (2010), which indicates that there exists room for improvement in the regional allocation of transportation infrastructure investment to enhance the allocative efficiency and further the national economic growth. Although there exists a need for interpretive caution, we estimated that the equity concern was more prominent for roads in particular than for the overall transportation infrastructure.

Second, according to the model setup and estimate ($\hat{\rho} < 0$) of this study, we could infer that the capital stock of transportation infrastructure in the ROK was accumulated excessively during the analysis period. This result is similar to that of Ryu (2006), who revealed that the majority of transportation infrastructure was oversupplied in most regions in the ROK by estimating the ratio of public to private capitals by region. The result is also in line with Lee and Choe (2010), who concluded that the size of the government sector was excessive compared with the private sector, as the marginal productivity of public capital was about 2/3 of that of private capital.

Third, the allocation of transportation infrastructure by region was not made on the basis of user demand. This finding is again similar to Lee and Choe (2010), who showed that the gap in marginal productivity of public capital is considerably larger than that of private capital by region in the ROK and is widening over time. The marginal productivity gap should be narrowed if public investments are allocated by region according to user demand. However, this result may be due to a road-oriented investment trend in the ROK. When all types of transportation infrastructure are considered, the demand for railroads, airports, and ports may not significantly affect investment decisions, as their share in the total transportation infrastructure is small.

Fourth, there exists political influence on the regional allocation of transportation infrastructure to some extent. The estimation result indicates that the political influence by election productivity standards is statistically significant in the cases of the entire transportation infrastructure and roads; the more voters compared with population and the more competitive the last election is, the more investment will be made. One could also argue that the political influence in relation to roads was greater than the entire transportation infrastructure.

Fifth, the allocation of transportation infrastructure did not sufficiently consider regional financial conditions. Admittedly, this factor may be less important as the central government's decision to allocate investment resources requires diverse policy considerations other than regional financial conditions, and in many cases, the central government uses the national treasury to build transportation infrastructure. The equity concern in road investment was relatively higher compared with the overall transportation infrastructure in light of the fact that the growth in road traffic did not have a significant effect on the investment. Moreover, the investment increases in regions with shrinking regional tax revenue in the estimation results of the model with roads only.

On the basis of the results of this analysis, the policy implications and suggestions for the regional allocation policy of public investment can be summarized as follows. First and foremost, a regional investment allocation strategy that is more efficient must be established. Of course, the need for policy to promote BRD by reducing the gap between regions in allocating transportation infrastructure also deserves recognition. However, based on the finding of this study that the allocation of transportation infrastructure emphasized equity, the efficient allocation of investment from the mid- to long-term perspectives to improve the overall productivity of the country should be considered more carefully.

Particularly, in the reality of the ROK, where the government mainly uses public investment as a critical part of fiscal policy for stimulating the economy, regional allocation to improve efficiency is a highly important policy task. Therefore, the regional allocation strategy for public investment must be planned by focusing on improving efficiency when establishing mid-term fiscal policies, such as the NFMP. For example, after measuring the marginal productivity of transportation infrastructure by region, an investment plan that reduces the gap between regions from a mid- to long-term perspective may be set up. Moreover, acknowledging that aging transportation infrastructure is increasing in the ROK, the allocation of investment priorities between the implementation of new projects and the maintenance of aging existing facilities should be judged based on efficiency. In the PFS as an effective gatekeeping *ex ante* evaluation of large-scale public investment projects in the public investment management system of the ROK, the evaluation based on equity must be suppressed so as not to be excessive.

Second, the supply of transportation infrastructure must be properly assessed and adjusted. The oversupply of transportation infrastructure implies a shortage of funds to be allocated to more efficient sectors. Control of supply includes allocation of resources within transportation infrastructure sectors. In view of the tradition of road-oriented investments in the ROK, the construction of a portfolio of transportation infrastructure based on efficiency through careful analysis in the future is recommended. In this regard, readers can refer to Kim and Song (2014) for a comparison of the trends of marginal productivity reduction in the road and railway sectors and inferred excessive investment in the road sector.

Third, user demand should be given more focus when allocating transportation infrastructure by region. Although data sources such as the Korea Transport Database (KTDB) are currently used for the PFS and similar feasibility assessments of transportation infrastructure, the KTDB and transportation big data should be used actively and extensively from the inception stage of planning. The related public data should be disclosed as much as possible to promote research and discussion to facilitate the feedback to policies. Furthermore, policy makers may consider applying different matching rates for regions based on their fiscal capacity to impose higher proportion of the central government's responsibility for regions with lower fiscal independence. If a region suffers from poor endowment in which the infrastructure gap is large (i.e., the infrastructure demand exceeds the supply by a large margin), the central government's subsidy can be effective to increase the regional investment due to the incentive compatibility of the policy scheme.

Fourth, methods to minimize political influences on the regional allocation of transportation infrastructure must be found, including some institutional mechanism to curb politically motivated projects. Possible measures include: (a) the operation of a transparent PFS system to secure independence and objectivity, (b) the disclosure of minutes of the closed meetings of the coordination subcommittee on the budget bills and special grant status by region, and (c) the expansion of users' cost-bearing based on the "user-pays principle" when allocating public infrastructure by region to avoid the tragedy of the commons.

Given that this study is the first attempt to find determinants of the regional allocation of infrastructure using a structural model and data of the ROK, it has limitations and future research challenges. As noted above, considering the estimation burden, data limitations, and main interests of this study, interactions between regions were not included in the model when setting up the production function. In this regard, if data that can represent the network effect or spatial ripple effect can be acquired in the future, this study's model should be supplemented to allow interregional interactions.

Moreover, there may be a room to improve the estimation results by augmenting the setting of political variables in the future. However, notably, some restrictions may hinder the choice of additional political variables. For example, to control the difference in the magnitude of political influence due to the personal characteristics of politicians, observable variables such as seniority can be considered, although the discrepancy between the electoral jurisdictions and administrative units limits the use of personal variables in many cases.

Future research topics may include establishing a model whose primary interest is features included in this study and empirically testing them. For example, the model in this study can be modified to shed lights on the substitutability between the central and regional government investments and the optimal and appropriate levels of the capital stock of transportation infrastructure.

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효율성인가, 형평성인가? 한국 인프라투자 지역 배분의 결정요인

이 종 연*

초 록 본 연구는 구조모형을 이용하여 2001~2014년의 기간 동안 한국의 지역별 교통인프라투자 배분 시 효율성과 형평성 중 어떤 측면이 강조되었는지를 살펴보고자 하였다. GMM(generalized method of moment) 추정법을 이용한 추정 결과, 한국의 공공투자는 효율성 증진보다 형평성 강화에 중점을 두고 이루어졌음을 발견하였다. 또한 실증분석 결과, 교통인프라의 자본스톡이 이론적 최적 수준을 상회하고 있으며, 중앙정부와 지방정부의 투자는 서로 대체관계에 있음을 확인하였다. 반면 지역의 인프라 수요 및 재정 상황은 투자 배분에 제한적인 영향을 미쳤음을 알 수 있었다. 마지막으로 인프라투자에 대한 정치적 영향은 당파성(partisanship)보다는 선거생산성(electoral productivity)의 측면에서 발현됨을 확인하였다.

핵심 주제어: 효율성-형평성 간 상충관계, 교통인프라, 공공투자, 정치경제
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